Ministry of Environmental Protection and Natural Resources of Ukraine

UKRAINE'S GREENHOUSE GAS INVENTORY 1990-2021

(draft)

Annual National Inventory Report
for Submission under the United Nations Framework
Convention on Climate Change and the Kyoto Protocol

Kyiv - 2023

FOREWORD

The Ukraine's Greenhouse Gas (hereinafter GHG) Inventory Report (hereinafter - National Inventory Report, NIR) is submitted for consideration of the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The National Inventory Report contains the balance of GHG emissions and removals for the period from 1990 through 2021 with a detailed description of the methods applied and findings of scientific researches of national circumstances. The National Inventory Report was prepared in the framework of the national inventory system, which includes the complex of all the organizational, legal, and procedural mechanisms adopted by Ukraine for estimating anthropogenic GHG emissions and removals, as well as for the purpose of reporting in accordance with the revised Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual greenhouse gas inventories (FCCC/CP/2013/10/Add.3), taking into account the structure of the report proposed in the appendix to Annex I of Decision 24/CP.19 ("An outline and general structure of the national inventory report").

The state authority responsible for preparation, approval, and submission of the National Inventory Report is the Ministry Environmental Protection and Natural Resources of Ukraine (hereinafter - MEPR).

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The National Inventory Report was prepared by the MEPR and the Budget Institution "National Center for GHG Emission Inventory" (hereinafter referred to as BI "NCI").

We thank everyone who was involved in preparing of this report for their contribution and support. The list of authors can be found in Chapter 12 of this report.

EXECUTIVE SUMMARY

ES.1 Background information on greenhouse gas inventories

The Verkhovna Rada (Parliament) of Ukraine has ratified the United Nations Framework Convention on Climate Change (UNFCCC) on October 29, 1996. Ukraine became a Party to the UNFCCC on August 11, 1997. In accordance with Articles 4 and 12 of the UNFCCC, Ukraine as a Party to the UNFCCC have the commitments to develop, periodically update, publish, and submit to the UNFCCC Secretariat national inventories of anthropogenic emissions by sources and removals by sink of all GHGs not regulated under Montreal Protocol.

This report is part of the Ukraine's Greenhouse Gas Inventory. It presents calculation results of national GHG emissions and removals in the period of 1990-2021 and describes the methods used to perform the calculations.

The duties of ensuring the inventory of anthropogenic GHG emissions by sources and removals by sink at the national level in order to prepare the NIR, as well as its approval and submission to the UNFCCC Secretariat, as mentioned above, is assigned to the MEPR.

The inventory covers emissions of seven GHGs:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs);
- sulfur hexafluoride (SF_6);
- nitrogen trifluoride (NF_3).

As well as following precursor gases:

- carbon monoxide (CO);
- nitrogen oxides (NO_x);
- non-methane volatile organic compounds (NMVOCs)
- sulfur dioxide (SO_2).

Chapter 1 provides background information on climate change and general information on GHG inventories. This chapter chapter provides a brief description of the basic principles and methods of GHG emission and removal estimations, description of key quality assurance and quality control categories and procedures (QA/QC). The final part of this chapter is focused on assessment of the overall uncertainty of the NIR and its completeness.

Chapter 2 describes and explains trends in both total emissions and removals of GHGs and precursors, as well as detailing by gas and by sector.

Chapter 3 to 9 describe specific sectors and categories of GHG sources and sinks. These chapters describe methods that were used to estimate GHG emissions and removals, sources of activity data and emission factors, QA/QC procedures applied, emission recalculations conducted, and planned improvements in the context of the specific categories.

Chapter 10 contains detailed information regarding recalculations of GHG emissions, and improvements made comparing with previous submission.

In addition to the main chapters as described above, the NIR contains eight annexes containing more detailed information, not included in these chapters: in-depth analysis of the key categories; description of the methods for calculating emissions in particular categories; comparison of emissions in case of the reference and sectoral approaches and analysis of any discrepancies arising; assessment of completeness and uncertainty of the inventory; consideration of recommendations and encouragements, gained from ERT during the process of annual inventory review.

ES.2 Summary on national trends of emissions and removals

As a result of the occupation and attempted annexation of Crimea and armed aggression by the Russian Federation, since 2014 slightly over 7 % of the territory of Ukraine temporarily remains out of control of the Government of Ukraine[1]. This fact complicates, and sometimes makes impossible, the process of data collecting and reporting, needed for the annual National GHG Inventory.

The temporary occupation by the Russian Federation territory of Ukraine is steadfastly condemned by international community, territorial changes by force are not recognized, sanctions remain in place till full compliance of the RF with international law. In particular, the UN General Assembly resolution 68/262 of March 27, 2014 «Territorial Integrity of Ukraine» confirmed the internationally recognized borders of Ukraine and the absence of any legal basis to change the status of the Autonomous Republic of Crimea and the city of Sevastopol. The same stance was confirmed by the UN General Assembly resolution 71/205 "Situation of human rights in the Autonomous Republic of Crimea and the city of Sevastopol (Ukraine)" of December 19, 2016, which unambiguously defines Russia as an occupying power. Besides that, numerous documents in support of Ukraine's territorial integrity within its internationally recognized borders were approved by the Committee of Ministers of the Council of Europe, Parliamentary Assembly of the Council of Europe, OSCE Parliamentary Assembly and other international organizations.

It should be noted that the ongoing armed aggression of the Russian Federation against Ukraine has a strong negative impact on the overall economic situation in Ukraine and has led to the reduction in industrial production.

Thus, for emission and reduction estimations on temporarily occupied by the Russian Federation territory of Ukraine expert estimation was performed, and the results of the inventory are an aggregation of this assessment with the results of inventory made on the basis of official data for the years 2014-2021 for the rest of the territory of Ukraine.

GHG emissions in Ukraine in 2021 amounted to 330.41 Mt CO_2-eq. excluding LULUCF, what is 65.0 % lower than in the base 1990 level, but 3.9 % higher than in 2020. With the LULUCF sector, emissions in 2021 amounted to 344.64 Mt CO_2-eq. and decreased in comparison with base year by 62.2 %, but increased by 8.5 % in comparison with 2020.

The largest share of GHG emissions in the base year is carbon dioxide - 74.0 % with LULUCF. Methane emissions in 1990 were 20.1 %, and those of nitrous oxide - 5.9 %. In 2021 carbon dioxide remained the largest emitted gas – 66.0 % of all GHG emissions, with 20.8 % and 12.7 % of methane and nitrous oxide respectively.

CO_2 emissions take place in all sectors, as well as removals of CO_2 in the LULUCF sector. CO_2 emissions in 1990 amounted to 674.59 Mt and decreased as of 2021 by 66.3 %, to the level of 227.34 Mt (Table ES.2.1). The economic decline that followed the collapse of the USSR in 1991 led to initial significant reduction of energy consumption, and thus in decreasing of CO_2 emissions. In the period from 2000 through 2007, CO_2 emissions stabilized with a slight upward trend. Despite the increase in CO_2 emissions in this period was due to growth of the economy, the emissions are not directly correlated with the rate of economic development. This was due to restructuring of the economy, outstripping growth in the trading, services, and the financial sector compared to industrial production, which made a significant contribution to GDP growth in this period. The second important factor that had a significant impact on CO_2 emission trends in this period was modernization of production, which made possible to reduce energy consumption, and, correspondingly, CO_2 emissions, i.e. carbon-intensity of major commodity group production.

CO_2 emission trend in 2008-2021 was determined by the influence of the global financial and economic crisis in 2008-2009 and a temporary occupation by the Russian Federation territory of Ukraine in 2014, which largely determined commodity production in the major export-oriented industries (metallurgy, chemical, mechanical engineering, etc.), which in turn affect supply sectors -

[1] On 18 January 2018, the Parliament of Ukraine adopted the law "On the peculiarities of State policy on ensuring Ukraine's State sovereignty over temporarily occupied territories in Donetsk and Luhansk regions", which defines the legal status of certain areas of the Donetsk and Luhansk regions as temporarily occupied territories of Ukraine

electric power generation, mining (ore and coal mining)[2]. Recover of economy after strict anti-COVID-19 measures in 2020 resulted in increase of GHG emissions in all sectors, except Waste.

Totals of 2015-2021 are presenting the results of number of factors, connected with overall economy growth of Ukraine, structure and amount of fuels used in Energy and industry products outputs.

Moreover, during the entire time series since 1990 to 2007 GHG removals were decreasing in LULUCF and in 2011-2019 and 2021 the sector became a net source, what was connected mainly with national practices of cropland and grassland management, as well as forestry.

In 2020 significant changes in C-emissions and removals occurred in LULUCF sector, which led to rapid drop of emissions (please see chapter 6 for more details).

Emissions of CH_4 are the second largest after CO_2 if considering their share in total GHG emissions. In 2021 CH_4 emissions in Ukraine amounted to 71.57 Mt CO_2-eq., what is 60.9% lower compared to 1990, and by 0.6 % than in 2020 (Table ES.2.1). The largest CH_4 source in the energy sector is coal mining, as well as the processes of production, transportation, storage, distribution, and consumption of oil and natural gas. In agriculture, the main source of CH_4 emissions is enteric fermentation of cattle. The economic decline and structural changes were accompanied by reduction in agricultural production, which led to reduced methane emissions in the Agriculture sector in 2021 to 324.32 kt, what is more than five times lower than in 1990.

Nitrous oxide emissions in Ukraine with the LULUCF sector in 2021 amounted to 43.79 Mt CO_2-eq., which in comparison with 1990 (53.64 Mt CO_2-eq.) is 18.4 % lower (Table ES.2.1). Compared with 2020, emissions of nitrous oxide increased by 10.5 %. The dominant source of nitrous oxide emissions in Ukraine, as in the previous submissions, is the Agriculture sector - 87.9 % of total nitrous oxide emissions in 2021. Emission sources in this sector are the categories of agricultural soils and manure management. Moreover, N_2O emissions take place in the sector IPPU (5.7 %), Energy (3.5 %), Waste (2.5 %), as well as LULUCF (0.4 %).

Table ES.2.1 contains data on direct action GHG emissions expressed in the carbon dioxide equivalent.

[2] On 18 January 2018, the Parliament of Ukraine adopted the law "On the peculiarities of State policy on ensuring Ukraine's State sovereignty over temporarily occupied territories in Donetsk and Luhansk regions", which defines the legal status of certain areas of the Donetsk and Luhansk regions as temporarily occupied territories of Ukraine

Table ES.2.1. GHG emissions, Mt CO_2-eq.

Gas	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	Current year compared to base year, %
CO_2 (excluding LULUCF)	706.2	390.1	285.7	313.5	294.4	223.8	234.0	223.1	231.7	221.9	206.8	213.3	-69.8
CH_4	182.9	139.1	118.3	102.8	84.9	61.6	66.4	64.2	67.9	70.1	72.0	71.6	-60.9
N_2O	53.6	33.1	24.1	25.9	27.6	33.2	36.5	35.1	39.0	40.6	38.1	43.8	-18.4
HFCs*	NO	NO	15.7	285.1	743.9	801.6	921.4	1049.3	1395.8	1683.0	1747.0	1895.2	100.0
PFCs*,**	235.8	178.1	115.7	142.3	26.7	NO	NO	NO	NO	NO	NO	NO	-100.0
SF_6*	0.0	0.1	0.4	4.5	9.7	19.6	24.4	28.6	33.4	38.8	43.4	48.9	641194.7
NF_3*	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
Net CO_2 from LULUCF	-31.6	-32.4	-23.2	-9.3	-9.2	19.5	24.2	13.3	24.7	23.1	-1.1	14.0	-144.4
CO_2 (including LULUCF)	674.6	357.6	262.5	304.3	285.1	243.3	258.2	236.4	256.4	245.1	205.8	227.3	-66.3
Total (excluding LULUCF)	942.8	562.1	427.9	442.4	407.4	319.2	337.6	323.3	339.8	334.1	318.0	330.4	-65.0
Total (including LULUCF)	911.4	530.0	405.0	433.5	398.4	338.9	362.0	336.7	364.7	357.5	317.6	344.6	-62.2
Total (excluding LULUCF), including indirect CO_2	942.8	562.1	427.9	442.4	407.4	319.2	337.6	323.3	339.8	334.1	318.0	330.4	-65.0
Total (including LULUCF), including indirect CO_2	911.4	530.0	405.0	433.5	398.4	338.9	362.0	336.7	364.7	357.5	317.6	344.6	-62.2

*emissions quoted in kt CO_2-eq.

** there are no PFC emissions, as cooling agents containing the gas were not imported in 2011-2021

ES.3 Overview of source and sink category emission estimates and trends

In Ukraine, GHG emissions occur in the following sectors set by the IPCC:

- Energy;
- Industrial Processes and Product Use (IPPU);
- Agriculture;
- Land Use, Land Use Change and Forestry (LULUCF);
- Waste.

The largest GHG emissions in Ukraine take place in the Energy sector. In 2021, the share of this sector accounted for around 64 % without the LULUCF sector. About 76 % of emissions in this sector account for emissions in the Fuel Combustion category, which include the categories of Energy Industries, Manufacturing Industries and Construction, Transport, Other Sectors, and Other, as well as 24 % - emissions in the category of Fugitive Emissions from Fuels.

It should be noted that the share of GHG emissions in the category of Fugitive Emissions from Fuels in total GHG emissions in the Energy sector gradually increased in the period of 1990-2000: from 17.6 % in 1990 to 28.7 % in 2000. This period is characterized by aging of the infrastructure and industrial capital of the country. Since 2001, the proportion of emissions associated with fugitive fuels was gradually decreasing to 24.0 % in 2021, which is due to activities in the field of energy efficiency and energy source replacement implemented in the country.

Global pandemic of COVID-19 and measures against the disease slowed the economy resulting in decrease of GHG emissions in Energy sector in 2020. Particularly it affected energy industries, transport and other sectors.

The GHG emission structure is shown in Figure ES.3.1.

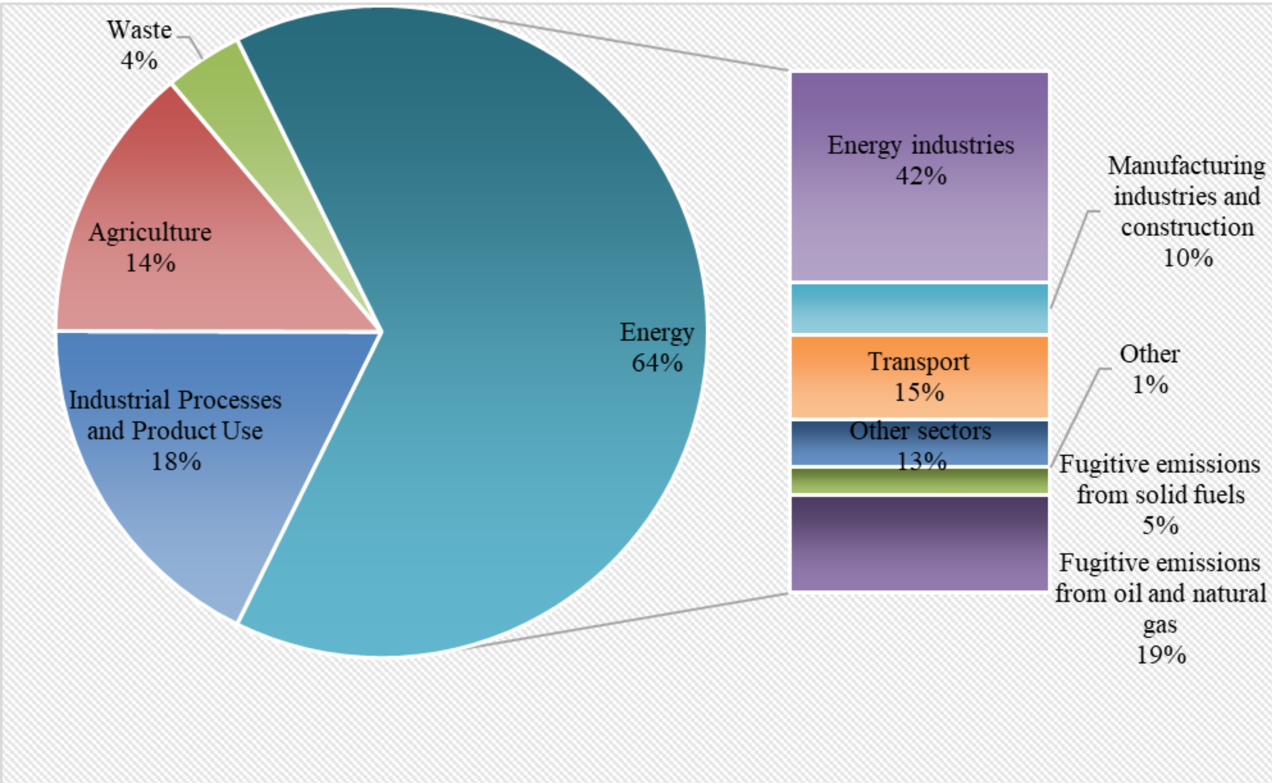

Fig. ES.3.1. The GHG emission structure by sources in 2021

The economic decline that followed the collapse of the USSR in 1991 led to significant reduction of production, energy consumption, and thus to lower CO_2 emissions. In the period between 2000 and 2007, there was some stabilization with a slight increase in production, and in the period since 2008, due to the global financial and economic crisis, there was a drop in production and, thus, in CO_2 emissions. In 2021, emissions in the IPPU sector decreased by 48.0 % compared to the base year. The key reasons for the reduction of emissions are the decreased production level due to the outflow of investment capital, unstable export dynamics, contraction of the domestic market, as well as the discrepancies in established "raw material-production-sales" connections in the regions of the country. Significant impact on industry development has situation on the East of the country. It is not only connected with catastrophic industry production drop in Donetsk and Lugansk regions. For neighboring regions, which had strong production-sales connections with Donbass region, it is challenging to compensate those losses by other supply chains.

2021 was characterized as recover of economy after the COVID-19 global pandemic. In the IPPU sector it is connected with the growth of emissions in the metal industry compared to drop in 2020.

The share of the Agriculture sector in total GHG emissions without LULUCF was 14.2 % in 2021. The major sources of emissions in the Agricultural sector are enteric fermentation and agricultural soils, 15.0 % and 80.0 % of the total emissions in the sector in 2021, respectively. Emissions in this sector decreased by 45.9 % compared to the base year, but rose by 12.8 % as compared to previous year mostly due to emissions in agricultural soils.

Changes in emissions over the reporting period in category 3.A Enteric Fermentation (-82.1 and -0.1 % to base and previous years respectively) is associated with the change in the number of livestock, herd structure and gross energy values.

The significant rate of methane emissions fluctuation in the category 3.B Manure Management in comparison with emissions in the other categories in the period of 1990-2021 is directly related to partial replacement in the structure of manure distribution at cattle breeding enterprises of liquid slurry MMS with solid storage: in 1990 the percentage of cattle manure in liquid slurry amounted to 21.0% of the total produced manure, while in 2021 − to only about 5.3%.

The methane emissions fluctuation in reported year (compared to the base year, as well as to the previous year) in category 3.C Rice Cultivation caused by a harvested area variation (from 27.7 kha in 1990 to 10.4 kha in 2021).

Nitrous oxide emissions change in category 3.D Agricultural Soils by 2021 is due to the changes in the amount applied fertilizers, areas under certain crops and their productivity.

The LULUCF sector includes both emissions and removals of carbon dioxide, as well as emissions of CH_4, and N_2O. The resulting values of the inventory in the LULUCF sector in 2021 is a net source. Net CO_2 emissions in the sector in 2021 is equal to 14.2 Mt CO_2-eq. compared to the net removals of 31.4 Mt CO_2-eq. in the base 1990 year. The main reason for such shift is change in agriculture management system on croplands, what has resulted in change from 4.6 Mt CO_2-eq. of removals in 1990 to 48.3 Mt CO_2-eq. of emissions in 2021. Particularly, significant influence has the areas, yield, and structure of harvested crops from those lands, as well as fertilizers applied. These factors also contributed to a rapid change in emissions compared with 2020 by 76.0 %, which is related to high yield of crops in 2021.

Also, big influence has decrease in peat extraction areas and volumes, what caused decrease in GHG emissions from 12.0 Mt CO_2-eq. in 1990 to 0.2 Mt CO_2-eq. in 2021.

Moreover, rapid changes in land use, especially those resulting in emissions from living biomass, has significant impact on general level of emissions in the sector.

The contribution of the Waste sector in 2021 in total emissions is 3.7 %. The main source of CH_4 emissions is landfills of municipal solid waste (MSW), and that of emissions of N_2O - human sewage. In relation to the base year, emissions in the sector decreased by 2.3 % in 2021.

Fig. ES.3.2 presents emissions as positive values and removals as negative.

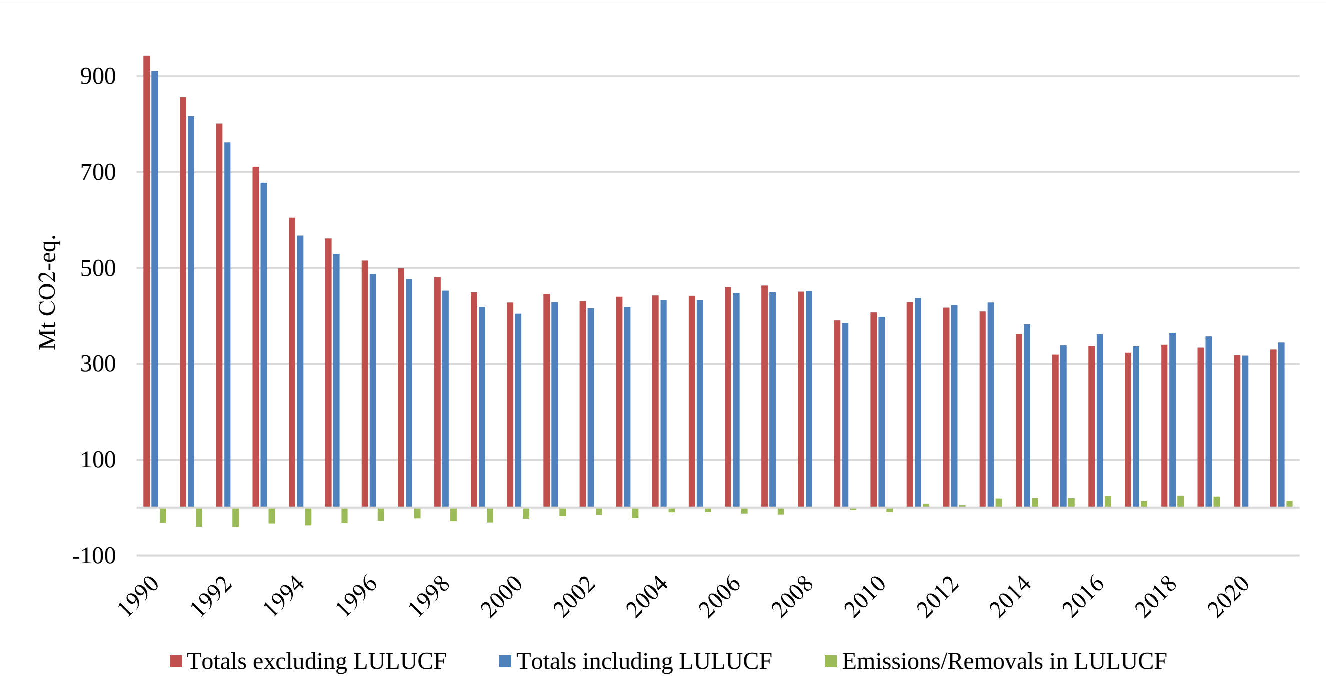

Fig. ES.3.2. Total GHG emissions (+) and removals (-) with and without the LULUCF sector, Mt CO_2-eq.

Table ES.3.1 reflects trends in aggregate GHG emissions by sector for the period of 1990-2021.

Table ES.3.1. Trends in aggregate direct action GHG emissions by sector, Mt CO_2-eq.

Sector	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	Current year compared to base year, %
Energy	725.3	431.4	311.3	315.1	286.4	210.8	224.8	217.8	226.3	219.2	208.0	209.7	**-71.1**
IPPU	118.2	58.2	67.5	81.0	74.7	56.4	58.1	51.9	56.5	57.6	56.0	61.5	**-48.0**
Agriculture	86.8	60.6	37.3	33.9	33.5	39.4	42.0	41.0	44.4	44.8	41.7	47.0	**-45.9**
LULUCF (removals)	-31.4	-32.1	-22.9	-8.9	-9.0	19.7	24.4	13.4	24.9	23.3	-0.4	14.2	**-145.3**
Waste	12.4	12.0	11.8	12.4	12.7	12.6	12.7	12.7	12.6	12.6	12.4	12.2	**-2.3**
Total (including LULUCF)	911.4	530.0	405.0	433.5	398.4	338.9	362.0	336.7	364.7	357.5	317.6	344.6	**-62.2**
Total (excluding LULUCF)	942.8	562.1	427.9	442.4	407.4	319.2	337.6	323.3	339.8	334.1	318.0	330.4	**-65.0**
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Total (excluding LULUCF), including indirect CO_2	942.8	562.1	427.9	442.4	407.4	319.2	337.6	323.3	339.8	334.1	318.0	330.4	**-65.0**

ES.4 Other Information

This section indicates sulfur dioxide and precursors emissions: nitrogen oxides, carbon monoxide, NMVOC. Precursor emissions take place in the Energy, IPPU, as well as Agriculture and LULUCF sectors. Table ES.4.1 reflects trends in summary precursors emissions and sulfur dioxide for the period of 1990-2021.

Table ES.4.1. Summary information on precursors emissions, kt

Gas	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	Change, %
NO_x	2273.8	1091.6	856.7	895.9	774.4	562.3	580.4	573.0	590.2	635.8	565.8	575.8	-74.7
CO	4323.0	1713.8	1213.6	1278.1	1149.8	927.1	822.9	854.4	864.7	933.8	965.5	759.8	-82.4
NMVOC	3539.2	2006.8	1492.6	1552.3	1211.1	858.6	868.5	801.2	812.0	910.6	681.2	692.4	-80.4
SO_2	1652.2	846.7	734.4	820.0	867.1	750.6	800.8	724.3	787.8	746.6	666.2	673.1	-59.3

Comparing with 1990, precursors and sulfur dioxide emissions in Ukraine decreased by 59.3-82.4 %. The main source of emissions of these gases is the Energy sector.

Estimations of indirect N_2O were also conducted which take place in Energy and IPPU sectors. The estimations are presented below, and detailed description as well as full time series are reported in Chapter 9.

Table ES.4.2. Summary information on indirect CO_2 and N_2O emissions, kt

Gas	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	Change, %
Indirect CO_2	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	NO, NE	-
Indirect N_2O	11.8	6.0	4.1	4.3	3.7	2.7	2.8	2.7	2.8	2.8	2.7	2.6	-77.9

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ABBREVIATIONS AND ACRONYMS

2006 IPCC Guidelines – 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories;

2013 Wetlands Supplement – 2013 Supplement to the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories: Wetlands;

AC – aircraft;

AD – activity data;

AFBR – Average Fuel Brand Representative;

AMS – Automated Monitoring Systems;

API – American Petroleum Institute;

AR – afforestation and reforestation;

ARR – report of the individual review of the annual submission of Ukraine;

BI «NCI» – Budget Institution «National Center for GHG Emission Inventory»;

BOD – Biochemical Oxygen Demand;

BOF – Basic Oxygen Furnaces;

CE – coal equivalent;

Cherkasky NIITEKHIM – Cherkasy Institute of Technical and Economic Information in the Chemical Industry;

CHP – combined heat and power plants;

CKD – Cement Kiln Dust;

CMP – Conference of Parties serving as the meeting of the Parties to the Kyoto Protocol;

COD – Chemical Oxygen Demand;

COP – Conference of Parties;

CRF – common reporting format;

CS – country specific;

CSC – Carbon stock change;

D – deforestation;

DC – decreasing coefficients;

DDB – departure database;

DOM – dead organic matter;

EAF – Electric Arc Furnaces;

EF – emission factor;

ERT – Expert Review Team;

FAO – Food and Agriculture Organization of the United Nations;

FEB – fuel and energy balance;

FM – forest management;

FMRL – forest management reference level;

GDP – gross domestic product;

GDS – system of gas distribution;

GE – gross energy;

GFFM – Gas fire fighting modules;

GHG – greenhouse gas;

GMS – gas metering stations;

GTS – gas transportation system;

GWP – Global Warming Potential;

HP – heating plants;

HWP – harvested wood products;

IA – Inhalation anesthesia;

IAC – Inter-Agency Commission of Climate Change and Ozone Layer Protection;

ICAO – International Civil Aviation Organization;

IE – Included elsewhere;

IEA – International Energy Agency;

IPPU – Industrial Processes and Product Use;

IS – International Standards;

JI projects – Joint Implementation projects;

KP Supplement – 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the KP;

LKD - Lime dust correction factor;

LPG – Liquefied Petroleum Gas;

LULUCF – Land Use, Land Use-Change and Forestry;

MCF – Methane correction factor;

MCTDIU – Ministry of Communities, Territories and Infrastructure Development of Ukraine;

MDMex – amount of manure excreted by animals in dry matter;

MEEP – Ministry of Energy and Environmental Protection of Ukraine;

MENR – Ministry of Ecology and Natural Resources of Ukraine;

MEPR – Ministry of Environmental Protection and Natural Resources of Ukraine;

Minecoenergo – Ministry of Energy and Environmental Protection of Ukraine;

MMS – manure management system;

MSW – municipal solid waste;

NA – Not applicable;

NAASU – National Academy of Agrarian Sciences of Ukraine;

NASU – National Academy of Sciences of Ukraine;

NCEA – National Classification of Economic Activities;

NCV – Net Calorific Value;

NE – Not estimated;

NG – natural gas;

NIR – National Inventory Report;

NJSC "Naftogaz" – National Joint-stock company "Naftogaz";

NO – Not occurring;

ODU – Oxidised During Use;

OHF – Open Hearth Furnaces;

OPF – One-component polyurethane foams;

PUF – Polyurethane foams;

PUL – limit of potential underestimation;

PV – Photovoltaic cells;

QA – quality assurance;

QC – quality control;

RD – revaluated data;

RPUF – Rigid polyurethane foams;

SAC – air-conditioning systems;

SC "Ukrtransgaz" – State Company "Ukrtransgaz";

SE "DergavtotransNDIproect" – State Enterprise "The State Road Transport Research Institute"

SE "UkrRTC "Energostal" – State Enterprise «Ukrainian Research & Technology Center of Metallurgy Industry «Energostal»;

SECB – Scientific Engineering Centre "Biomass" Ltd.;

SEIA – State Environmental Investment Agency;

SESU – The State Emergency Service of Ukraine;

SKD – Semi Knocked Down;

SOC – soil organic carbon;

SOM – soil organic matter;

SSSU – The State Statistics Service of Ukraine;

TEA – type of economic activity;

TFT-FPD – Flat panel displays on thin film transistors;

TPP – thermal power plants;

UGS – underground gas storages;

Ukrderzhlisproekt – Ukrainian State Project Forest Inventory Production Association;

URIFFM – Ukrainian Order "Sign of Honour" Research Institute of Forestry and Forest Melioration named after G.M. Vysotsky;

USSR – Union of Soviet Socialist Republics;

VPP – vacuum pump plants;

WIP – waste incineration plant;

WWTP – Waste water treatment plant;

XPS – Extruded polystyrene foam

1 INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 Background information on climate change

Climate of Ukraine is a temperate continental one, with subtropical Mediterranean climate at the South Coast of the Crimea. Generally, Ukraine gets sufficient amounts of heat and moisture, which create favorable natural and climatic conditions in its territory. However, those conditions have been changing substantially throughout recent decades, bringing about serious threats and challenges for country's sustainable development due to increased risks for human health, life and activities, natural ecosystems, and economy sectors.

The main manifestations of regional climate changes in Ukraine within the global warming processes include significant rise of air temperatures, changes of thermal regime and structure of precipitation, increased number of hazard meteorological phenomena and extreme weather events, which all result in losses for country's population and various economy sectors.

Global warming during recent decades is unequivocal, and the first decade of the 21st century turned out to be the warmest in the period of instrumental weather observations (since 1850). In the Northern hemisphere, the period of 1983 to 2012 was probably the warmest 30-year period in the last 1400 years [20].

Intensive increase of surface air temperatures has been also observed in Ukraine since mid-20th century. The rate of change of the average as well as minimum, and maximum annual temperatures in the country was 0.3^{o}C/10 years in 1961-2013. Since late 1990s, a stable transition of the annual air temperature anomaly to above 0^{o}C is observed (Fig.1.1). The period of late 20th and early 21st century was possibly the warmest one for the duration of instrumental weather observations in Ukraine (since 1890s) [3, 8, 13, 15, 17, 19].

Unfortunately, it is not possible to obtain reliable meteorological data for the whole territory of Ukraine since 2014 after the occupation and attempted annexation of Crimea. Information on hydrometeorological parameters from observation stations is not transmitted to Ukrainian Hydrometeorological Center, and, as a result, unavailable for aggregation. Therefore, the data on regional effects of the global climate change in Ukraine are limited by the year 2013.

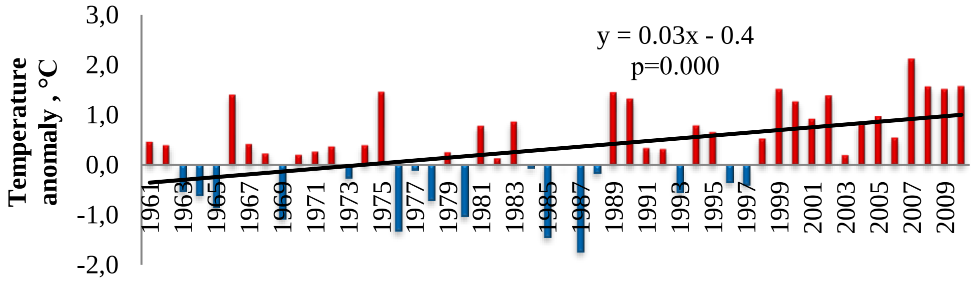

Fig. 1.1. Anomalies of annual air temperature in Ukraine with respect to the 1961–1990 reference period [3]

The summer and winter seasons are the main contributors to the change of annual temperature in Ukraine. Their average temperatures increased by 1.3 and 0.9^{o}C, respectively, in 1991-2013 (Fig.1.2). Also, the air temperature rise was the highest in January (2.3^{o}C) and July (1.4^{o}C). The average temperature in spring increased by 0.8^{o}C mostly due to temperature anomaly observed in March. There was only a minor change of autumn temperature (0.4^{o}C) [3].

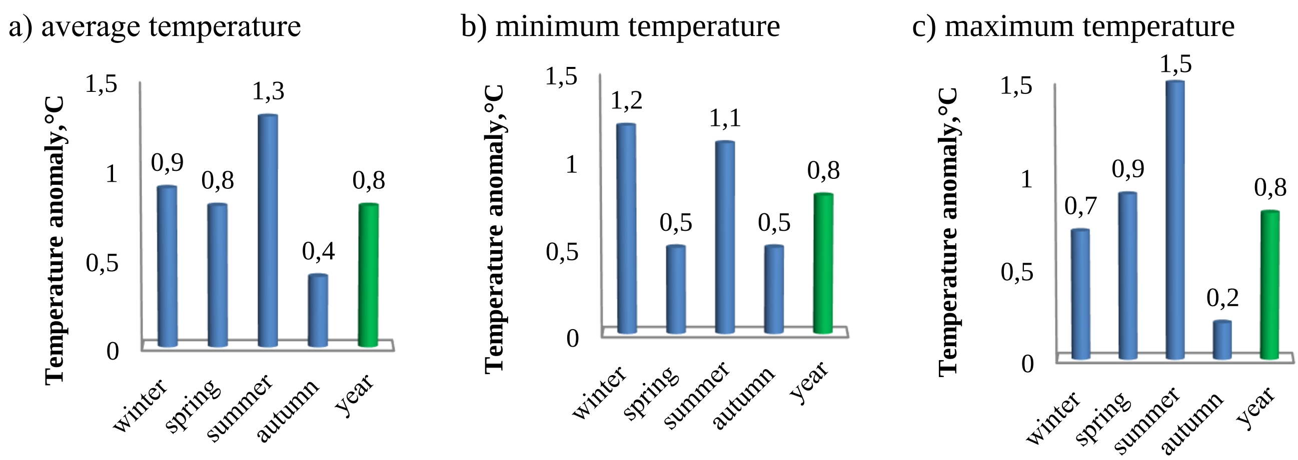

Fig.1.2. Anomalies of average (a), minimum (b) and maximum (c) air temperatures per seasons and year in 1991-2013 with respect to the 1961–1990 reference period [3]

Rise of the average annual and monthly air temperatures was determined by the increase of minimum and maximum temperatures throughout the whole year [3]. Also, as seen from Fig.1.2, a greater growth of minimum temperature is observed during a cold period (by 1.2°C in winter), while a growth of maximum temperature is evident for a warm period (by 1.5°C in summer). The average maximum temperature in spring increased by 0.9°C, while the minimum ones by 0.5°C. Minimum and maximum air temperatures in autumn have changed much less [3].

The change of temperature regime in Ukraine features regional aspects. The common pattern of the annual air temperature change in Ukraine in 1991-2013 with respect to the reference period is a growth in the magnitude of temperature anomalies moving from the south to the north and northeast [3]. Rising of annual air temperatures in the country's northeast was significantly greater than averaged over the whole country and made 1.2-1.4°C, while the magnitude of such changes was half as much (0.6°C) in Ukraine's south and in the Carpathian region. Annual air temperature at the South Coast of the Crimea changed insignificantly [3] (Fig.1.3).

Change in the isotherm positions reflects the spatial features of temperature regime change. Thus, the annual isotherms of 6°C and 7°C passed through the northeastern part of Ukraine in 1961-1990, isotherm of 8°C was located in the central regions of the country, and 9°C - in the southern regions. In 1991-2013, each isotherm shifted by 1°C almost throughout the territory of Ukraine [3], but the greatest changes are observed in the far northeast, where the isotherms of 6°C and 7°C are no longer presented, the isotherm of 8°C moved 300-400km northwards being passed through the northern regions of the country, the isotherm of 8°C instead of 7°C emerged in the west, and the isotherms of 9°C and 10°C instead of 8°C and 9°C appeared in the south (Fig.1.3).

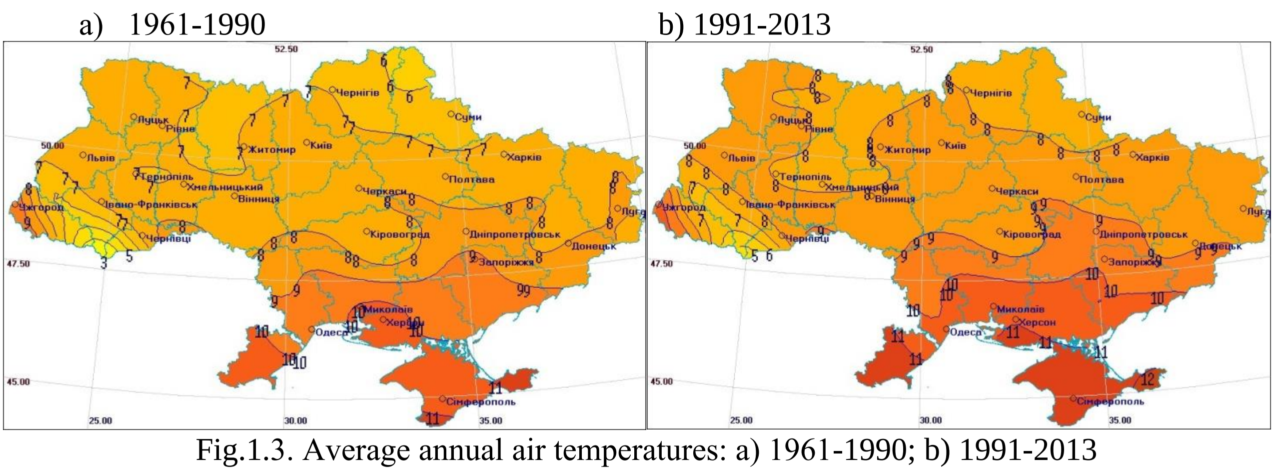

Fig.1.3. Average annual air temperatures: a) 1961-1990; b) 1991-2013

The seasonal changes of temperature regime in Ukraine also demonstrate regional variations. Winters in the second half of the 20th through early 21st century became warmer over the whole territory of Ukraine (Fig.1.4). The average winter air temperature increased by more than 1°C in 1991-

2013 compared to 1961-1990 over a significant part of country's territory [3]. In the north of the country, this growth exceeded 1.4°C, and positive temperature anomalies amounted to 1.6°C and above in the northern Sumy and Chernihiv oblasts. In the Autonomous Republic of Crimea, winter temperature increased by 0.2-0.6°C. Rising of average winter air temperature was caused mainly by the significant growth of minimum temperature. Positive anomalies of the average maximum temperature are also observed in the whole territory of the country in winter, but they are significantly lower than those of the minimum temperature.

a) average winter temperature anomalies | b) minimum winter temperature anomalies | c) maximum winter temperature anomalies

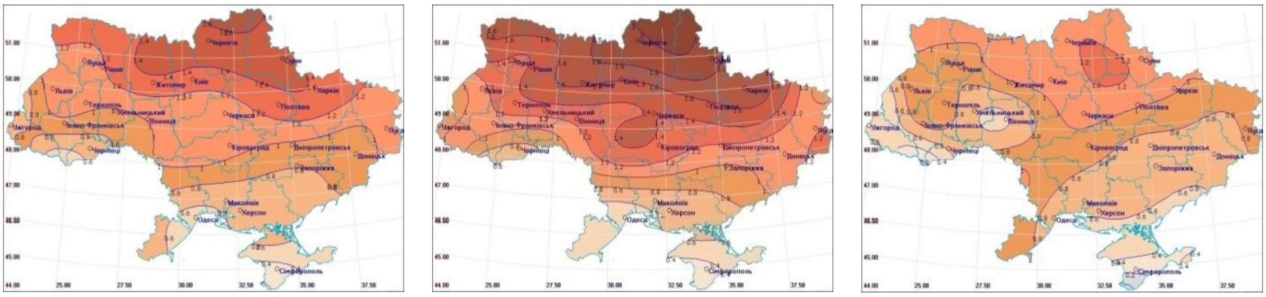

Fig. 1.4. Anomalies (°C) of average, minimum and maximum winter air temperatures in 1991-2013 with respect to the 1961–1990 reference period

Spring season became warmer in 1991-2013 compared to 1961-1990 almost over the whole territory of Ukraine with the exception of the southernmost parts of the Crimea [3]. The highest growth of average spring air temperatures (1.0°C and above) is observed in the far northeast of the country and in the Zhytomyr region (Fig.1.5). Some lowering of temperatures is observed in the Crimea, especially in the south of the peninsula. The average minimum air temperature in spring increased almost over the whole territory of the country, except the Luhansk oblast. Two regions stand apart, viz., the Volhynian-Podolian Upland and the left bank of the Dnipro River, where those changes are the most significant and make 0.6-0.8°C and above. The average maximum spring temperatures increased in the whole territory of the country in 1991-2013. The most significant changes are observed in the north, west, and southwest of the country amounting to 1.0-1.2°C and above [3].

a) average spring temperature anomalies | b) minimum spring temperature anomalies | c) maximum spring temperature anomalies

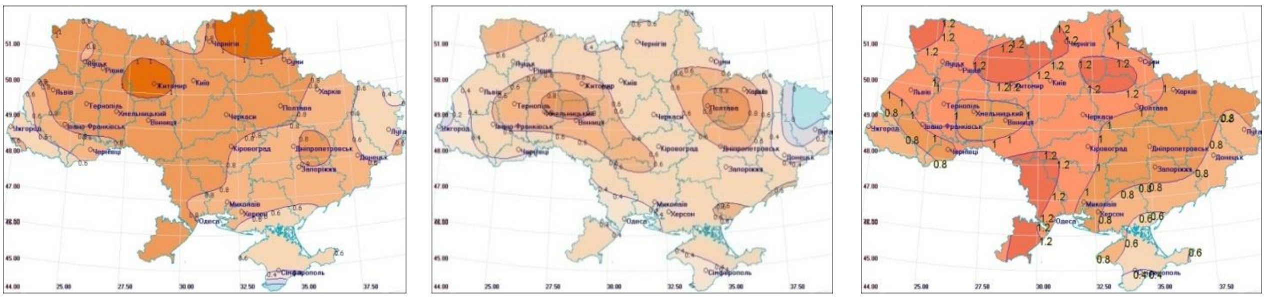

Fig. 1.5. Anomalies (°C) of average, minimum and maximum spring air temperatures in 1991-2013 with respect to the 1961–1990 reference period

Summers were much hotter in Ukraine compared to reference period in the second half of the 20th through early 21st century (Fig.1.6). A significant rise in the average summer air temperatures is observed ranging from 0.8-1.0°C in the east of the country to 1.4°C and above in the Transcarpathian region, in the Odesa oblast, and the South Coast of the Crimea [3]. Rise of the maximum summer air temperatures is significantly greater and intensifying from the east to the west and southwest of the country from 1.2-1.4°C to 1.6-1.8°C and above. The minimum summer air temperatures were also rising over the whole territory of the country. The anomalies of the average summer minimum temperatures were growing from the north and northeast to the south and southwest from 0.4-0.8°C to 1.2°C and above in 1991-2013 (Fig.1.6).

a) average summer temperature anomalies | b) minimum summer temperature anomalies | c) maximum summer temperature anomalies

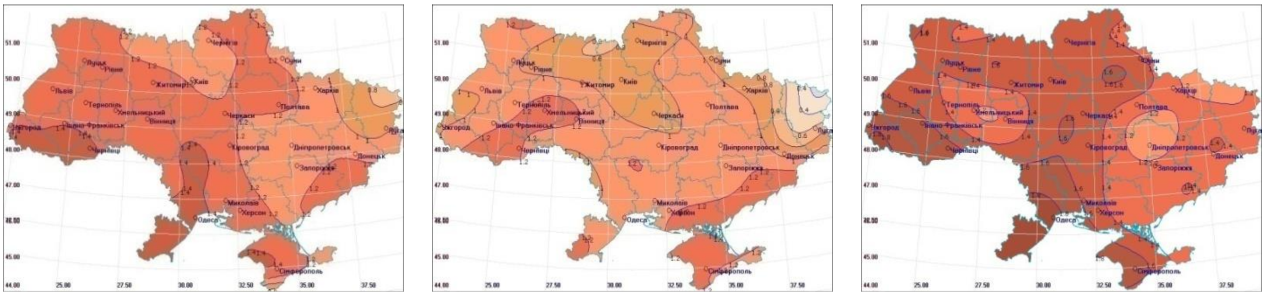

Fig. 1.6. Anomalies (°C) of average, minimum and maximum summer air temperatures in 1991-2013 with respect to the 1961–1990 reference period

Autumn temperatures also increased in Ukraine in 1991-2013 compared to the reference period, however, those changes are minor and their maximum values do not exceed 0.5°C [3]. Such changes are observed in the northeastern, central, eastern, and southern regions of Ukraine. Changes of the minimum temperature are inhomogeneous over the territory with the maximum values of positive anomalies reaching 0.6°C and above in the Volhynian-Podolian Upland and the northern part of the Volynska oblast, left bank of the Dnipro River, and north coast of the Sea of Azov [3]. The average minimum air temperatures in autumn changed marginally or even decreased in some areas in the northwest and far east of the country. Changes in the average maximum autumn temperatures were negligible in recent decades [3] (Fig.1.7).

a) average autumn temperature anomalies | b) minimum autumn temperature anomalies | c) maximum autumn temperature anomalies

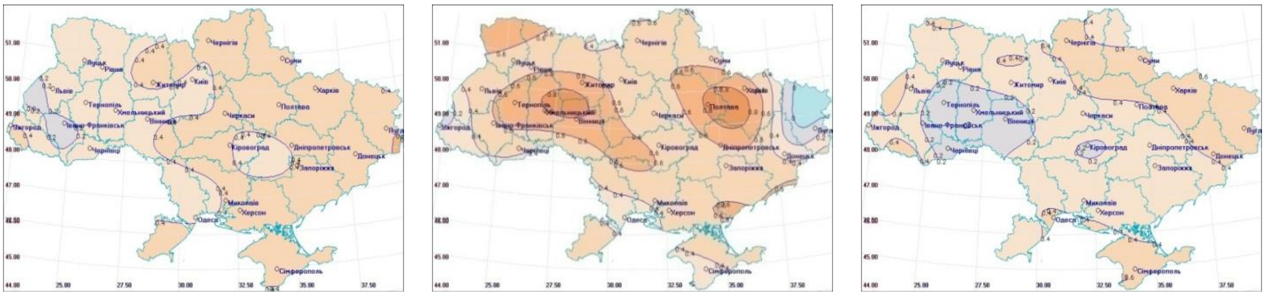

Fig. 1.7. Anomalies (°C) of average, minimum and maximum autumn air temperatures in 1991-2013 with respect to the 1961–1990 reference period

The trend is also observed in Ukraine towards increasing the duration of a warm period when average daily temperatures exceed 0°C [8]. In the Southern Steppe, in the Crimea and Subcarpathia, the warm period has become nearly two weeks longer (12 days) compared to the reference period. Moving further north, the period duration is growing. These changes already amount to 15-18 days in the Forest Steppe zone, and 22-24 days in the western and eastern Polissia. The greatest changes were observed in the central Polissia, where the warm period duration amounted to 278 days at the beginning of the 21st century, which is 40 days longer than the baseline long-time average value. Significant changes in the duration of the warm period were due to its earlier start in spring (by 13-19 days) and later end in all regions of Ukraine [8, 15].

Significant rising of air temperature in the warm period has led to an increase in the number of days with mean daily air temperatures above 15°C and, consequently, to an extended duration of the recreation period. A trend of increasing the frequency and duration of periods with high air temperatures (above 25, 30, 35°C – heat waves) is also observed, that significantly influences the human health and livelihood in Ukraine [4, 8, 15].

Rising of air temperatures in the warm period is not only observed near the ground, but also in the lower troposphere and leads to an increased convection intensity, and, consequently, to increased frequency and intensity of convective weather phenomena, such as thunderstorms, heavy rainfall, hail, squalls, and whirlwinds [1, 2, 6, 13, 15, 19]. These phenomena are sometimes recorded in the months and seasons, when they did not occur before, and extend to the territories, where they have never been observed.

Due to rising of both the minimum and maximum air temperatures in the cold period, the number of days with subzero temperatures, freezing cold days with minimum temperatures dropping below -10, -20, -25^oC, as well as the duration of extremely cold periods have decreased [17]. Rising of air temperatures in the cold period has significantly impacted on the frequency and intensity of extreme weather events and natural disasters of the cold period, such as shower snowfall, sleet, glaze and rime deposits. A trend towards their increase is observed in many regions of Ukraine [2, 6, 13-15, 19].

In the recent decades, the average and maximum wind speed is lowering that leads to decreasing the frequency of such related hazardous weather phenomena as blizzards and dust storms [2, 6, 13, 15, 19]. Reduction of wind speed accompanied by rise of air temperatures results in reduction of cold discomfort in winter and reduced severity of winters. At the beginning of the 21st century, winters have changed from the "moderately severe" to "lightly severe" category over the significant part of the Ukrainian territory.

In contrast to air temperatures, the change in annual precipitation sums was negligible in Ukraine (3-5%). The variations of annual precipitation in the recent period were within the climatic normal variability, but the amplitude of inter-annual variations decreased [4-6, 8, 13, 15, 19]. Notwithstanding the insignificant changes in the annual precipitation sums, their seasonal and monthly values have been redistributed. The greatest changes were observed in autumn, when a significant increase in the amount of precipitation was recorded (about 20%) with maximum in October. The winter precipitation decreased slightly. At the same time a number and intensity of hazardous and heavy precipitation events increased, especially in the warm period [2, 5, 6, 8, 13, 19].

Rising of air temperatures and non-uniform distribution of precipitation events, which are characterized as shower and local in the warm period and fail to ensure efficient accumulation of moisture in the soil, have led to an increased frequency and intensity of drought phenomena. Combined with other anthropogenic factors, this could result in growth of the area of risky farming and even desertification of certain areas in the southern regions of Ukraine. In the last 20 years, the incidence of droughts has nearly doubled. It is observed a dangerous trend towards increasing a occurrence of droughty conditions even within the zone of sufficient moistening, which covers the Polissia and northern part of the Forest Steppe [8,12,15,18].

The change of the temperature and precipitation regimes impacts on the physiological processes, which determine the life of the forest flora and fauna, leads to respective changes in the biota, which is a sensitive indicator of environmental conditions [6]. Phenological changes have been recorded in Ukraine, such as earlier flowering and shedding of leaves, and repeat development. The geographic ranges of plant species are changing significantly, and invasive species appear and spread rapidly. The latter include numerous hazardous weeds, allergens, agents of disease [6].

Rising of air temperatures accompanied by deficit of moisture has an adverse effect on woodlands, especially on growth of trees, increased incidence of diseases, and lead to drying of forests. The hazard of wild fires is growing. This hazard is exacerbated by increased thunderstorm activity [3,4,7,16].

The temperature regime change has a significant impact on energy supplies for human life and activities of the population. A shortening of the cold period and significant rising of winter air temperature results in a reduced duration of a heating season and lower demand for the thermal energy generation [8, 15]. At the same time, rising of air temperatures in the warm period leads to increased electricity consumption for cooling and air conditioning.

The regional effects of climate change are of special interest, which currently goes beyond the scope of scientific issues alone. Since different types of ecosystem response to the transformation of planetary processes, including those caused by anthropogenic effect, are recorded in different areas, there arises an acute need to identify their key trends and regularities. Such analysis is necessary for increasing the accuracy and reliability of forecasting all possible regional climate changes to address comprehensive applied tasks and implement local programs of adaptation to the climate change impact on climate dependent economy sectors.

To carry out a comprehensive analysis of possible regional differences of climatic conditions in Ukraine in the 21^{st} century, the ensembles of ten regional climate models (RCMs) for air temperature and of four RCMs for precipitation sums from the European project FP-6 ENSEMBLES for the scenario of greenhouse gas emissions IPCC SRES A1B have been elaborated. Absolute values for the forecast periods have been adjusted based on the simulated changes and the data of the gridded dataset E-Obs for the recent period of 1991-2010, employing the additive and multiplicative methods. The RCM ensembles have been developed by researchers of the Ukrainian Hydrometeorological Institute and identified as being optimal for the analysis and forecasting of the regional features of respective climate characteristics over the territory of Ukraine [21]. The analysis under climate projections has been conducted based on all nodes in the model grid of 25x25km separately and averaging over five selected regions and the country's territory in the whole. Individual regions West, North, East, South, and Center have been identified based on similarity of physiographic conditions and accounting for the country's administrative and territorial structure. Such zoning will contribute to subsequent use of research findings for strategic planning of socioeconomic development of individual regions, as well as for development and implementation of the climate change mitigation and adaptation actions.

Three 20-year forecast periods have been examined: 2011-2030, 2031-2050, and 2081-2100. The analysis of projections of average air temperatures has shown (Fig.1.8) that in the nearest period of 2011-2030, the average temperature over the territory of Ukraine will rise by 0.4-0.5°C, ranging from 0.1°C in the western region in spring and up to 0.8°C in the northeast in summer. In the next 20-year period (2031-2050), the average temperature for the territory will increased by 1.2-1.5°C against the present climate, ranging from 0.7°C in the west in spring and to 1.9°C in the northeast in winter. By the end of the century (2081-2100), the average temperature for the territory will rise by 2.9-3.3°C, with the minimum value of 2.1°C in the western region in spring, and the maximum temperature increase by 4.3°C in the southern region and in the south of the eastern region in summer. The smallest changes are projected for the western region in all seasons, as well as for all regions in spring for the whole century [9, 10, 11].

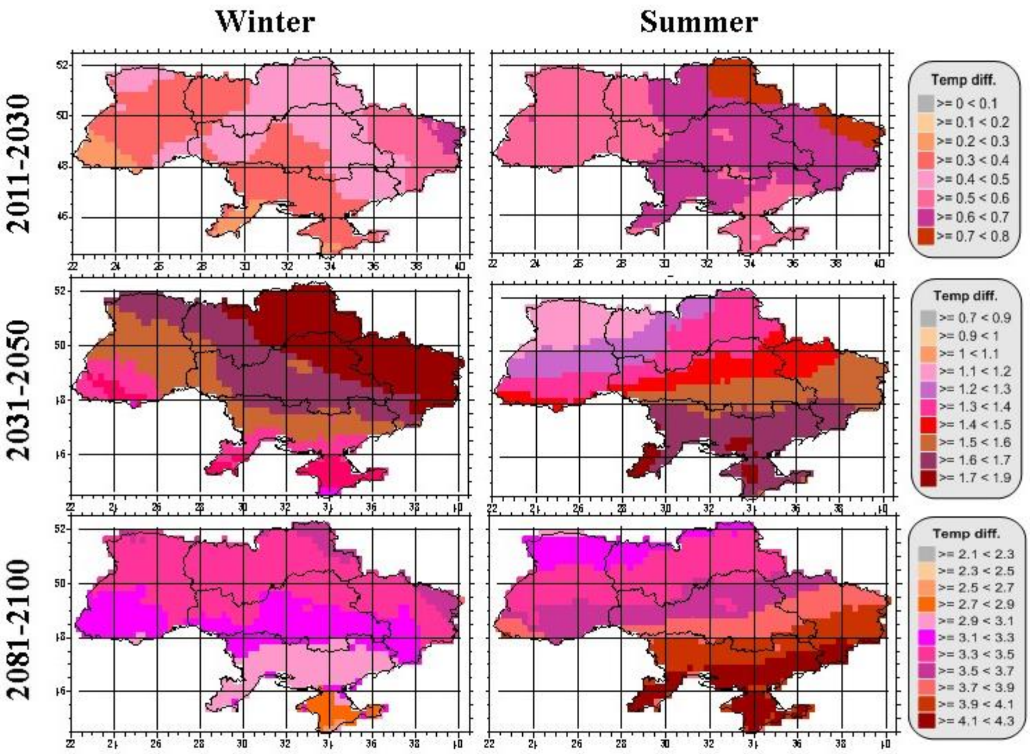

Fig. 1.8. Changes of air temperatures in winter and summer during the three forecast periods (2011-2030, 2031-2050, and 2081-2100) against the present period of 1991-2010 for ensemble with ten RCMs

The main trends of the projected climate conditions in Ukraine in the 21^{st} century are as follows. There will be no winter climatic season in the far west and southern region by the end of the century, as average temperatures in winter months above 0^oC have been obtained. At the same time, average monthly summer temperatures above 25^oC are projected for the central, eastern, and southern regions by the end of this century. As is apparent from the obtained values, the change of climatic conditions will significantly impact the duration of climatic seasons in Ukraine in the future.

As regards the moisture regime, both increase and decrease of average monthly and seasonal precipitation is projected for the territory in all the reviewed periods. In the nearest period (until 2030), precipitation will be decreasing by up to 20% in the central, northern, and southern regions in summer and autumn, and will be increasing by up to 42% in the west, north, and east in winter and spring. By the middle of the century (2031-2050), precipitation will be decreasing by up to 30% in the central, southern, and eastern regions in summer, and increasing by up to 50% in the western, northern, and eastern regions and in the eastern part of the southern region in winter and spring. By the end of the century (2081-2100), precipitation will be decreasing by up to 40% in the southern, central, and eastern regions in summer and will be increasing by more than 40% and up to 50% in the west and north in the winter and spring seasons. Therefore, the maximum increase of average monthly precipitation is expected in winter and spring in the country's west and north in all the forecast periods. A decrease in the amount of precipitation is projected in the summer and autumn seasons in the central, southern, and eastern regions in all future periods.

1.1.2 Background information on greenhouse gas inventories

Ukraine signed the UNFCCC in June 1992 year, and became Annex I Party of the UNFCCC in August 1997 year.

According to Decision 3/CP.5 adopted at the 5th session of the UNFCCC Conference of Parties, each of Annex I Parties must submit its annual National Inventory Report, which includes detailed and complete information for the entire time series in accordance with the guidelines of the UNFCCC.

The National Inventory Report was prepared in accordance with the revised "Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual greenhouse gas inventories" (FCCC/CP/2013/10/Add.3), taking into account the structure of the report proposed in the appendix to Annex I of Decision 24/CP.19 ("An outline and general structure of the national inventory report"). The preparation was carried out with in line with the requirements of Decision 6/CMP.9 on application of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.

GHG emission assessment in Ukraine was carried out under general methodological guidance of the 2006 IPCC Guidelines.

Submission to the UNFCCC Secretariat contains also GHG inventory results in the common reporting format (CRF), as well as CRF tables for reporting information on activities in accordance with paragraphs 3 and 4, Article 3 of the Kyoto Protocol, in accordance with Decision 14/CP.11 and 2/CMP.8.

The inventory covers emissions of seven GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3).

There is data on precursor emissions also - carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs), as well as data about emissions of sulfur dioxide (SO_2).

To bring emissions of various gases to the carbon dioxide equivalent, the inventory used IPCC data on values of the global warming potentials of GHGs, stated in AR4 and contained in Annex III of the revised "UNFCCC Annex I National Inventory Reporting Guidelines, part I: UNFCCC guidelines for reporting annual greenhouse gas inventories", adopted at the nineteenth session of the Conference of Parties.

1.2 Institutional arrangements for National Inventory Report preparation, including legal and procedural arrangements for inventory planning, preparation, and management

1.2.1 Overview of institutional, legal, and procedural aspects of preparing the National Inventory Report

In order to ensure regulatory and organizational support for GHG inventory, the President Decree was signed, and several Resolutions of the Cabinet of Ministers of Ukraine were adopted. According to Decree of the President of Ukraine of September 12, 2005 of No. 1239/2005 the MENR is authorized as the coordinator of activities for the implementation of Ukraine's commitments under the UNFCCC and Kyoto Protocol to it. To execute the Decree, the Cabinet of Ministers of Ukraine adopted two Resolutions.

Resolution of the Cabinet of Ministers of Ukraine of April 21, 2006 of No. 554 established procedures for the national anthropogenic GHG emissions and removals not controlled by Montreal Protocol evaluation system, and defined its objectives and functions. Later this Resolution of the Cabinet of Ministers of Ukraine was amended (in line with the new Resolutions of the Cabinet of Ministers of Ukraine of July 16, 2012 No. 630, of December 04, 2019 No. 630, of September 09, 2020 No. 826). The changes mainly concerned the ways of the national system's functioning – additional information (data) request procedure for estimation of anthropogenic GHG emissions and removals, indicating the limited timing for data transfer (provision) by providers (in this case, these are public authorities and institutions, plants, etc.) – within 30 days from the date of receipt of the request.

In turn by the Order of the MENR of January 31, 2017 No. 35 «On approval of the Structure of the Ministry of Ecology and Natural Resources of Ukraine», amendments were introduced that influenced the structure of the central apparatus of the MENR, namely the Department of Climate Change and Ozone Layer Protection was set up.

According to Resolution of the Cabinet of Ministers of Ukraine of September 02, 2019 No. 829 «Some Issues of Optimization of the System of Central Executive Government Bodies», the decision was made to rename of the MENR to the Ministry of Energy and Environmental Protection of Ukraine (hereinafter – MEEP).

In turn by the Order of the MEEP of February 11, 2020 No. 83 «On approval of the Structure and number of independent structural units of the MEEP», amendments were introduced that influenced the structure of the central apparatus of the MEEP, namely the Directorate of Climate Change and Ozone Layer Protection was set up.

According to Resolution of the Cabinet of Ministers of Ukraine of May 27, 2020 No. 425 «Some Issues of Optimization of the System of Central Executive Government Bodies», the decision was made to rename of the MENR to the Ministry of Energy of Ukraine and create a Ministry of Environmental Protection and Natural Resources of Ukraine (hereinafter – MEPR).

In accordance by the Order of the MEPR of July 08, 2020, the new structure was approved, namely the Department of Climate Policy and Ozone Layer Protection was set up.

In turn by the Order of the MEPR of August 29, 2022 No. 327, the new MEPR apparatus structure was approved, namely the Department of Climate Policy and Ozone Layer Protection was set up.

For more details on these functions, see the information in the Generalized Scheme of the National GHG Inventory System in Ukraine (Fig. 1.9).

1.2.2 Planning, preparation, and management of the process of greenhouse gas inventory

One of foundational documents within the system of inventory process planning, including preparation of the NIR with its further submission and support during review by the UNFCCC Secretariat, as well final archiving, is Order of the Ministry of Environmental Protection of May 31, 2007 of No. 268 About approving the Work Plan for Annual Preparation and Maintenance of the National

Inventory of Greenhouse Gas Emissions and Removals and the Work Plan to Maintain and Control the Quality of Activity Data and Calculations for the Annual Preparation of the National Inventory Report of Emissions and Removals of Greenhouse Gases.

Until September 09, 2014, the SEIA of Ukraine served as the only national body, that was responsible for preparation of the NIR and its submission to the Secretariat of the UNFCCC. In line with the functions delegated to it, the SEIA of Ukraine carried out general planning of the inventory, as provided for in Resolution 19/CMP.1. In particular, it defined and allocated specific responsibilities in the inventory development process, including duties directly associated with the choice of methodologies, collection of primary data, data on activities of ministries, agencies, and other entities, processing and archiving of data, as well as Quality Assurance and Quality Control procedures. As part of the planning, the SEIA of Ukraine considered the ways to improve the quality of functioning of the National System for estimating GHG emissions and removals and of preparing the NIR. For that operational and medium-term planning were applied.

According to Resolution of the Cabinet of Ministers of Ukraine of September 10, 2014 No. 442 «On Optimizations of Central Executive Authorities», the decision was made on elimination of the SEIA of Ukraine and delegating its functions to the MENR. Consequently after amendments to the Ministry's apparatus by Order of the MENR of January 31, 2017 No. 35 the Department of Climate Change and Ozone Layer Protection was formed. The Department of climate policy functioned before October 31, 2016 in accordance with the order of the mayor of May 12, 2015 № 147.

According to Resolution of the Cabinet of Ministers of Ukraine of September 02, 2019 No. 829 «Some Issues of Optimization of the System of Central Executive Government Bodies», the decision was made to rename of the MENR to the MEEP.

Consequently after amendments to the Ministry's apparatus by Order of the MEEP of February 11, 2020 No. 83 the Directorate of Climate Change and Ozone Layer Protection was formed.

According to Resolution of the Cabinet of Ministers of Ukraine of May 27, 2020 No. 425 «Some Issues of Optimization of the System of Central Executive Government Bodies», the decision was made to create a MEPR. In turn by the Order of the MEPR of July 08, 2020, the new structure was approved, namely the Department of Climate Policy and Ozone Layer Protection was set up. Subsequently, by Order of the Ministry of Natural Resources dated August 29, 2022 No. 327, the new MEPR apparatus structure was approved with the Department of Climate Policy and Ozone Layer Protection.

Creation, development, and functioning of the national system of inventory of anthropogenic GHG emissions and removals are governed by the applicable Ukrainian legislation. The National Inventory System includes:

- State and private organizations and enterprises, as well as private entrepreneurs and individuals who being primary subjects of holding or control of GHG sources and sinks shall submit activity data for GHG inventory, as well results of its production activities by type of products;
- Public and private corporations being primary subjects of holding or control of GHG sources and sinks, or including primary subjects of primary subjects of holding or control of GHG sources and sinks, which submit activity data for GHG inventory within the corporation by individual GHG sources or sinks and their categories, as well as results of its production activities by type of products;
- Industrial, regional, and local governmental agencies, which in line with the acting regulatory framework of Ukraine and within their authority shall collect statistical information and submit to the request of the MEPR respective aggregated activity data for GHG inventory in accordance with the forms agreed with the Department of Climate Policy and Ozone Layer Protection of MEPR;
- Research institutions involved into collection and preliminary processing of data on GHG emissions and removals or into development of calculation methods;
- independent experts and organizations involved in public discussion of the inventories;
- civic and non-governmental organizations involved in public discussion of inventories;
- the Budget Institution «National Center for GHG Emission Inventory», which in cooperation with other actors in the systems, conducts inventory of anthropogenic GHG emissions by sources and removals by sinks at the national level;

- Inter-Agency Commission on implementation of the UNFCCC, which reviews and approves reporting documents submitted to the UNFCCC Secretariat;
- MEPR is the main body in the system of central executive authorities regarding development and enforcement of the national policy in the field of environmental protection, provides legal regulation within this area, reviews and approves reporting documents submitted to the UNFCCC Secretariat. Within its assigned tasks, the MEPR provides is responsible for inventory of anthropogenic GHG emissions by sources and removals by sinks at the national level in order to prepare the NIR, as well as approval and submission to the UNFCCC Secretariat of the NIR. As a structural unit of the MEPR, the Department of Climate Policy and Ozone Layer Protection is still performing its duties.

Funding of preparation of the NIR is provided from the state budget of Ukraine.

Preliminary version of the National Inventory Report and the CRF-tables are published by the MEPR on its official website to inform public organizations and all stakeholders so that they could submit their comments and suggestions for improvement. Simultaneously with uploading of the document on the website for free access, requests are sent to independent experts (senior specialists) in the field of GHG inventory in order to obtain expert judgements on particular categories, as one of the components of QA procedures. Stakeholder organizations and experts can submit their comments and suggestions to the draft version of the National Inventory Report within 30 days, which is followed by their presentation for public hearing (discussion). The final version of the NIR – revised and updated with regard to received recommendations – is submitted for consideration by the Inter-Agency Commission of Climate Change and Ozone Layer Protection in accordance with Resolution of the Cabinet of Ministers of Ukraine of September 23, 2020 of No. 879. As a result of consideration by the Inter-Agency Commission, the MEPR submits the official version of the NIR and CRF tables to the UNFCCC Secretariat.

A generalized diagram of the National Inventory System in Ukraine is shown below in Fig. 1.9.

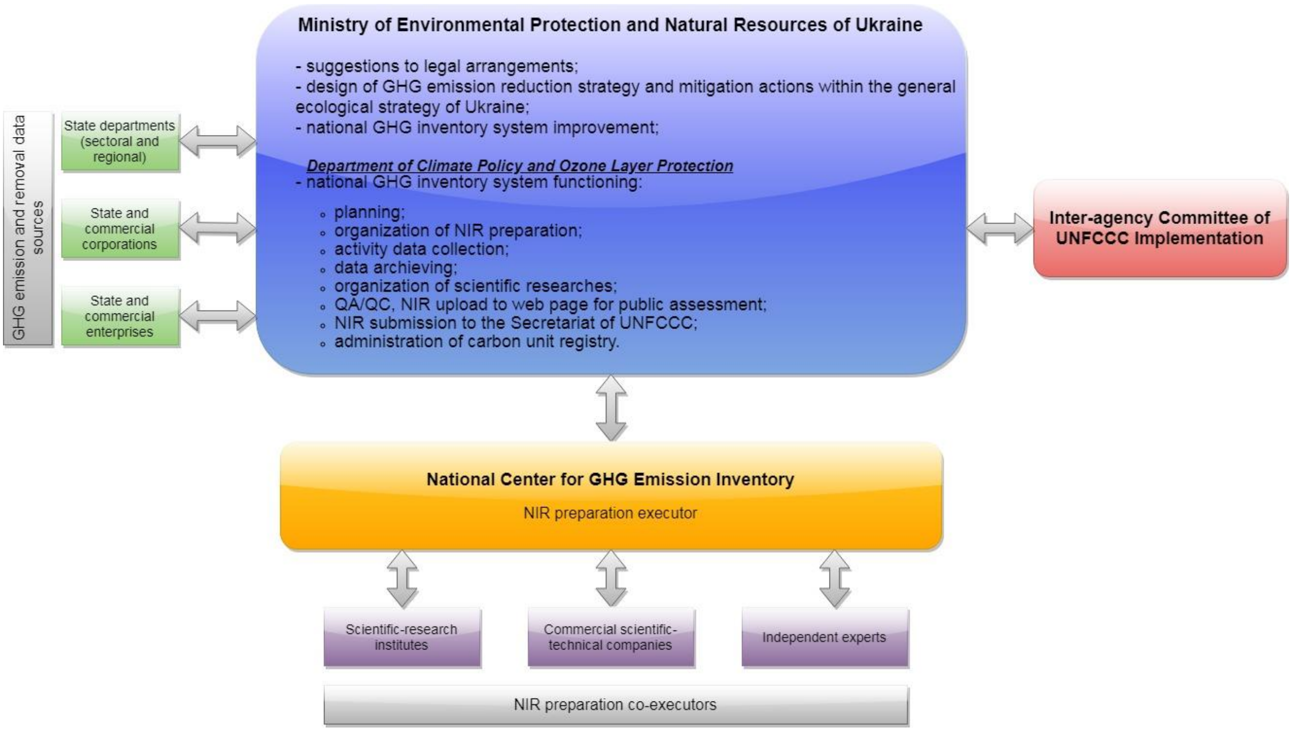

Fig. 1.9 Generalized diagram of the National Inventory System in Ukraine

Capacity building and knowledge exchange

In the framework of the project Clima East CEEF2015-041-UA "Capacity building of the national GHG inventory system in terms of the development of methodological recommendations for determining national GHG emission factors from the use of motor fuels in the transport sector" performed by SE «GosavtotransNIIproekt», a science-based platform was developed for the transition to higher levels of GHG emissions calculation in category 1.A.3.b Road Transportation, taking into account national specific features of fuel use by mobile sources is under formation (ERT Note, «Report on the individual review of the inventory submission of Ukraine submitted in 2015", paragraph E.13, p. 8).

Scientific research "Verification of motor fuel consumption by road transport within the context of annual National Inventory Report preparation" was accomplished by the Institute of Industrial Ecology. The work was performed on the contract between the Institute of Industrial Ecology and Embassy of Denmark In Ukraine acting on behalf of the Danish Energy Agency. The research performed calculation of physical and chemical properties of fuels (gasoline, diesel fuel, LPG, LNG). Fuel consumption by road and off-road transport was also estimated, what has allowed to perform GHG emission calculation by Tier 3 method for entire time series for years 1990-2016.

Scientific research "Development of Data Base on Energy Statistics of Ukraine for 1990-2016 and Improvement the Transparency of National Reporting on GHG Emissions in Energy Sector" was accomplished by the Non-governmental organization "Bureau of integrated analysis and forecasting". The work was performed on the contract between the Non-governmental organization "Bureau of integrated analysis and forecasting" and Royal Danish Embassy in Ukraine on behalf of Ministry of Energy, Utilities and Climate of The Danish Energy Agency. The research developed a Data Base on Energy Statistics of Ukraine for 1990-2016 and Improvement the Transparency of National Reporting on GHG Emissions in Energy Sector.

Within the framework of expert facility project Clima East, supported by EU, two projects were accomplished in LULUCF sector: "Improving reporting system for carbon storage and emissions accounting from harvested wood products (HWP) in the National GHG inventory" and "Development of the GHG emissions inventory in the forestry sector in order to improve national reporting of Ukraine according to the requirements of the UNFCCC and the Kyoto Protocol".

The first report aimed in developing recommendations for GHG inventory methodology on HWP best suited for Ukrainian conditions. Also recommendations were developed to accommodate national statistics into methodology, as well as to the national statistics in order to be more consistent with the methodology.

The second report provided recent scientific approach towards Carbon stock change estimations, developed by International Institute for Applied System Analysis, Austria. The experts made pilot calculations based on forest inventory of 2011 year. Moreover, recommendations were developed on possible alternative approaches of monitoring of GHG emissions and removals in forests, as well as to forest policy makers with regard to future forest inventories.

In order to further improve the National system of anthropogenic GHG emission and removals estimations and according to the Request on the submission of proposals to the prospective plans for 2020-2022 from the MEEP, in 2019 the experts of BI «NCI» updated a list of necessary research projects (13 items).

During 2020-2021, BI "NCI" experts took part in meetings of the subsidiary bodies and workshops of the Secretariat of the UNFCCC, as well as other conferences and forums, in particular:

- Regional Workshop On Measurement, Reporting And Verification (MRV), Vienna, Austria; Copenhagen, Denmark, February 17-19, 2020;
- Twentieth Meeting of the Technology Executive Committee (TEC) of UNFCCC on-line, April 01-03, 2020;
- Seventeenth meeting of lead reviewers for greenhouse gas inventories, on-line, June 29 – July 03, 2020;
- Review of GHG Inventory Submissions submitted by Austria and Sweden in 2020 remotely, September 21-26, 2020;
- Twenty First Meeting of the Technology Executive Committee (TEC) of UNFCCC, on-line, November 17-20, 2020;
- Ex-Ante Carbon Balance Tool v.9 training, on-line, April 19-23, 2021;
- Twenty Second Meeting of the Technology Executive Committee (TEC) of UNFCCC, on-line, April 20-26, 2021;
- May–June 2021 Climate Change Conference, on-line, May 31 – June 17, 2021;
- All-Ukrainian Forum Ukraine 30. Ecology, Kyiv, Ukraine, June 07-09, 2021;

– Workshop "Strategies and modalities to scale up implementation of best practices, innovations and technologies that increase resilience and sustainable production in agricultural systems according to national circumstances", Glasgow, Scotland, October 28-30, 2021;

– Twenty-sixth session of the Conference of the Parties to the UNFCCC, Glasgow, Scotland, October 31 – November 11, 2021;

– Webinar "Proposals preparation for the National Action Plan of the introduction of climate-friendly technologies", on-line, December 10, 2021;

– BTR training programme: 2nd meeting with the CGE&LRs, on-line, October 5, 2022;

– Preparatory meeting of the Lead Reviewers under the ETF, on-line, October 6, 2022.

1.2.3 Quality assurance, quality control and planning of inspections. Details of the QA/QC plan

QA/QC in the national inventory system is based on planning, preparation, quality control and subsequent improvements, and is an integral part of the inventory process.

For this purpose, regular checks of transparency, consistency, comparability, completeness of data, calculations, measures to identify and eliminate errors, as well as to store inventory information are conducted (performed), which represent the QA/QC system.

The system complies with Tier 1 procedures described in Chapter 6, «Quality Assurance/Quality Control and Verification» of 2006 IPCC Guidelines, and expanded with a number of QA/QC procedures specially designed taking into account sector specifics in accordance with Tier 2.

For more detailed information on implementation of QC procedures for individual categories, see the relevant sections of the NIR.

1.2.3.1 QA/QC procedures

In the framework of the National Inventory System, throughout the NIR development cycle, including its final submission to the UNFCCC Secretariat, implementation of QA/QC procedures is an important component, compliance with which is provided and clearly defined by the internal documents – the general plan of measures for the development of NIR and additional plan for QA/QC. More specified information can be found in Chapter 1.3.2 «Planning and control of activities on greenhouse gas inventory and report development».

Organization of this work is regulated in accordance with the regulations, guidelines, requirements, and procedures outlined in the 2006 IPCC Guidelines and consideration of recommendations provided by the ERT, authorized by the Secretariat of UNFCCC.

It should also be noted that in Ukraine there are further efforts being made to implement requirements of International Standards (IS) ISO 9000 into the National Inventory System.

Constantly in the action plan for the NIR preparation on the stages of QC special attention is given to errors likelihood minimization in the calculations, correspondence of data in the NIR and CRF tables in all the sectors. In particular, enhancements have been considered and introduced into QC reporting forms.

The QA/QC process at all stages of the work performed with documentation and final archiving of all information, including results of support of NIR through all stages of the ERT review.

General view of the QA/QC system for the NIR is presented in Fig. 1.10.

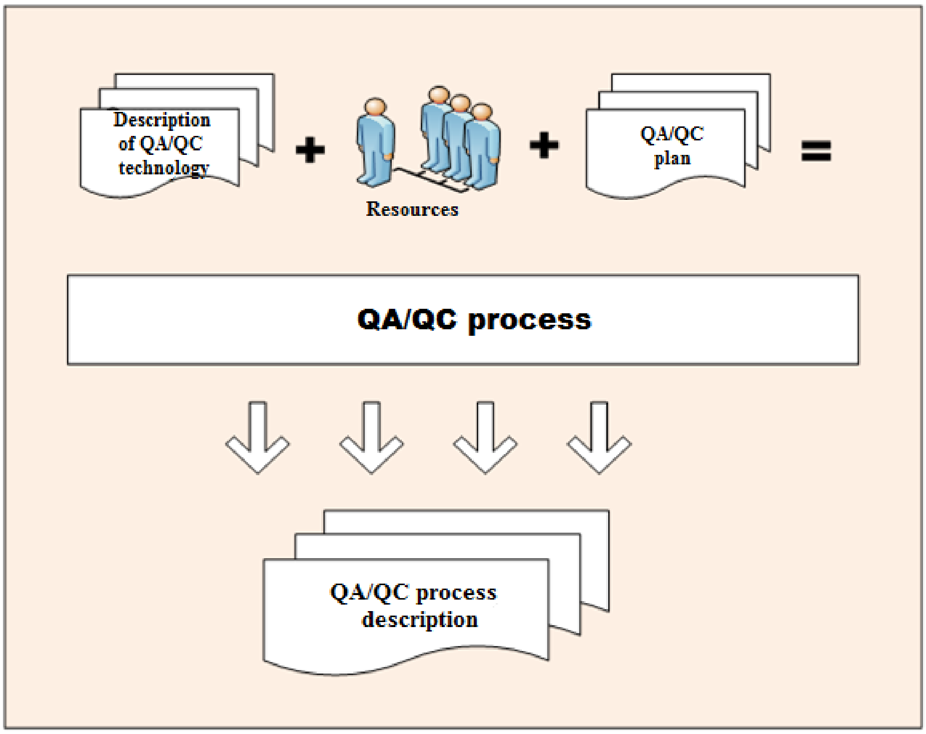

Fig. 1.10. The quality assurance/control system of the NIR

The QA/QC system of Ukraine includes the following basic components:

- **QA/QC technology**, which determines the QA/QC methods and QA/QC supporting tools.
- **Resourcing** – experts, involved in implementation of the QA/QC plan with the QA/QC technique available in accordance with distribution of the roles, described in «Roles and Responsibilities».
- **QA/QC plan**, which is maintained by the GHG inventory QA/QC manager, determines the specific quality objectives and required activities to ensure QA/QC. The plan sets out quality assurance and control activities, responsibilities, and timing for performance of the necessary QA/QC activities.
- **QA/QC process (implementation)**, which includes physical conducting of QA/QC based on the available technique with the available resources in accordance with the plan for all the phases of data collection, compilation, public discussion, independent review, and submission of annual emission assessment cycle reporting.
- **Description of the QA/QC process** – documenting and archiving, which provide information about the process at a certain detailing level delivery for further use.

The Scope of the QA/QC plan

The QA/QC plan covers all activities at all stages of QA/QC that are integral parts of the process of development and review support of the National Inventory Report.

Quality objectives

The key objective of the QA/QC plan is to ensure that estimates of GHG emissions and removals are:

- ➢ **Transparent** regarding data sources, used to perform the estimates, calculation methods applied, as well as documentation of QA/QC activity implementation process;
- ➢ **Complete,** i.e. they will include all possible emissions/removals, socio-economic indicators and policies, as well as activities for all the required years, gas categories, and scenarios;
- ➢ **Consistent** taking into account emission trends for the entire time series and with regard to internal consistency of emission data aggregation;
- ➢ **Comparable** with other emission estimates provided through use of new reporting templates, correct level of IPCC categories etc.;
- ➢ **Accurate** in application of methods and use of the appropriate IPCC recommendations.

Roles and responsibilities

In the process of implementation of the various QA/QC activities, specific responsibilities are assigned to the various roles in the process of emission assessment:

- QA/QC manager supports the QA/QC plan, establishes quality objectives, coordinates QA/QC activities, manages data supplies from providers, sectoral experts, and independent experts, supports cross-cutting QA/QC activities;
- Sectoral experts conduct sector-specific QC activities and report to the QA/QC manager. Sectoral experts also must cooperate with data providers and other stakeholders to review estimations and conduct QA/QC for data provided;
- Outsourced expert consultants are the organizations and individuals who perform QA/QC consultancy activities;
- External expert reviewers are the organizations and individuals who perform peer reviews and provide feedbacks on NIR by specific sectors.

1.2.3.2 Quality control and documentation

QC of the NIR takes place throughout the data collection, compilation, and reporting cycle. The data check system used in the NIR is illustrated in Figure 1.11.

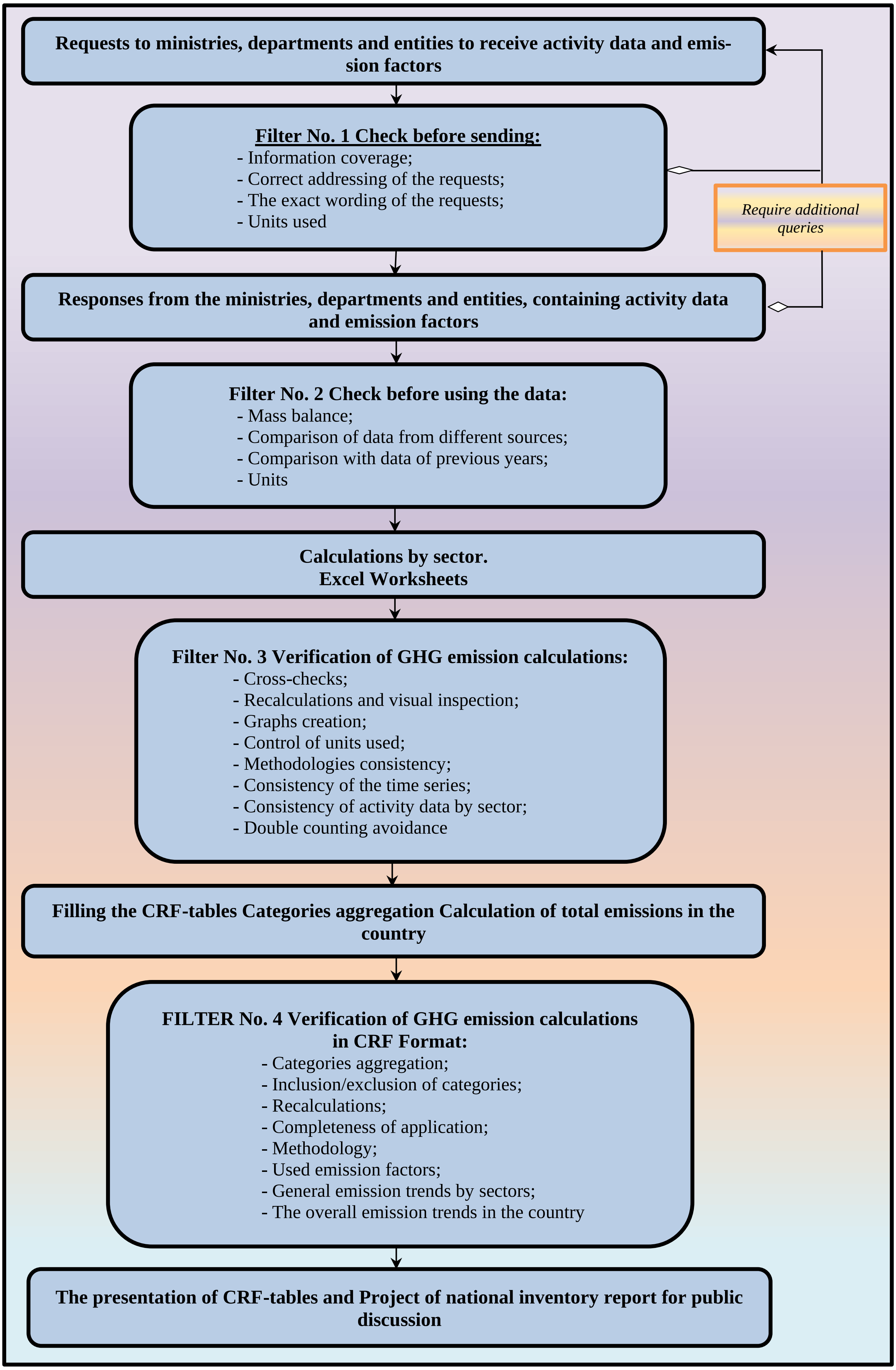

Figure 1.11. The general scheme of the quality assurance process

Checks and documentations are supported by data storage and processing designed specifically for NIR compilation, which include:

➢ **External information database**, which is part of the data repository, data storage. It contains information about suppliers of activity data, detailed specification requirements for data, including templates and data provision procedure, as well as incoming activity data, provided by suppliers for the NIR to estimate emissions in the process of inventory compilation. All input and output information for each annual inventory report are stored in the relevant sections of the repository.

➢ **Individual data processing and QC performance tools** that are used to convert the majority of input data into the corresponding aggregated activity data and, using emission factors, to estimate emissions in Ukraine.

QC procedures may be general with possible broadening to procedures of particular categories. They include sector-specific checks (e.g. the energy/weight balance, country-specific emission factors).

Data processing tools are electronic spreadsheets that include the information necessary to perform QC procedures.

➢ **The key information database** is used to store all emission estimates for reporting, including the CRF format, responses to non-regulated questions, and description of review or recalculation procedures. This guarantees it that conversion of historical data can be easily traced and summarized in the reports. Most of the data are imported into the database directly from data processing tools (the spreadsheets described above). All the key data for each annual NIR are stored in the relevant sections of the repository.

Archiving. As part of inventory management, good practice recommends documenting and archiving all information required to prepare national GHG inventory estimates in accordance with requirements of the 2006 IPCC Guidelines, as well as timely provision of required information requested by the ERT.

At the end of each annual reporting cycle, all repository files, spreadsheets, regulatory and methodological documents, electronic data sources, notification records, paper data sources, output files representing all the calculations for complete time series «freezing» and archiving. Electronic data are stored on hard disks, for which backup is performed regularly. Paper information is archived in a shelved storage, while the repository stores an electronic record of all archived elements.

In general QC measures prescribed in the QA/QC plan are based on 2006 IPCC Guidelines (Chapter 6, «Quality Assurance/Quality Control and Verification», Tab. 6.1) and are described in Table 1.1.

Table 1.1 Types of quality control activities

	Type of control activity
1.	Check whether assumptions and criteria for the selection of activity data, emission factors, and other estimation parameters were documented
2.	Check for errors in data input transition and references
3.	Check the correctness of emissions and removals calculations
4.	Check whether parameters and units are correctly recorded and that appropriate conversion factors are used
5.	Check the integrity of database files
6.	Check for consistency in data between source categories
7.	Track of inventory data correctness among processing steps
8.	Check whether uncertainties in emissions and removals are estimated and calculated correctly
9.	Conduct time series consistency check
10.	Conduct completeness checks
11.	Conduct trend checks
12.	Conduct review of internal documentation and archiving

The development of NIR is performed with checks according to the scheme of Fig. 1.12 with types of QC activities described in table 1.1.

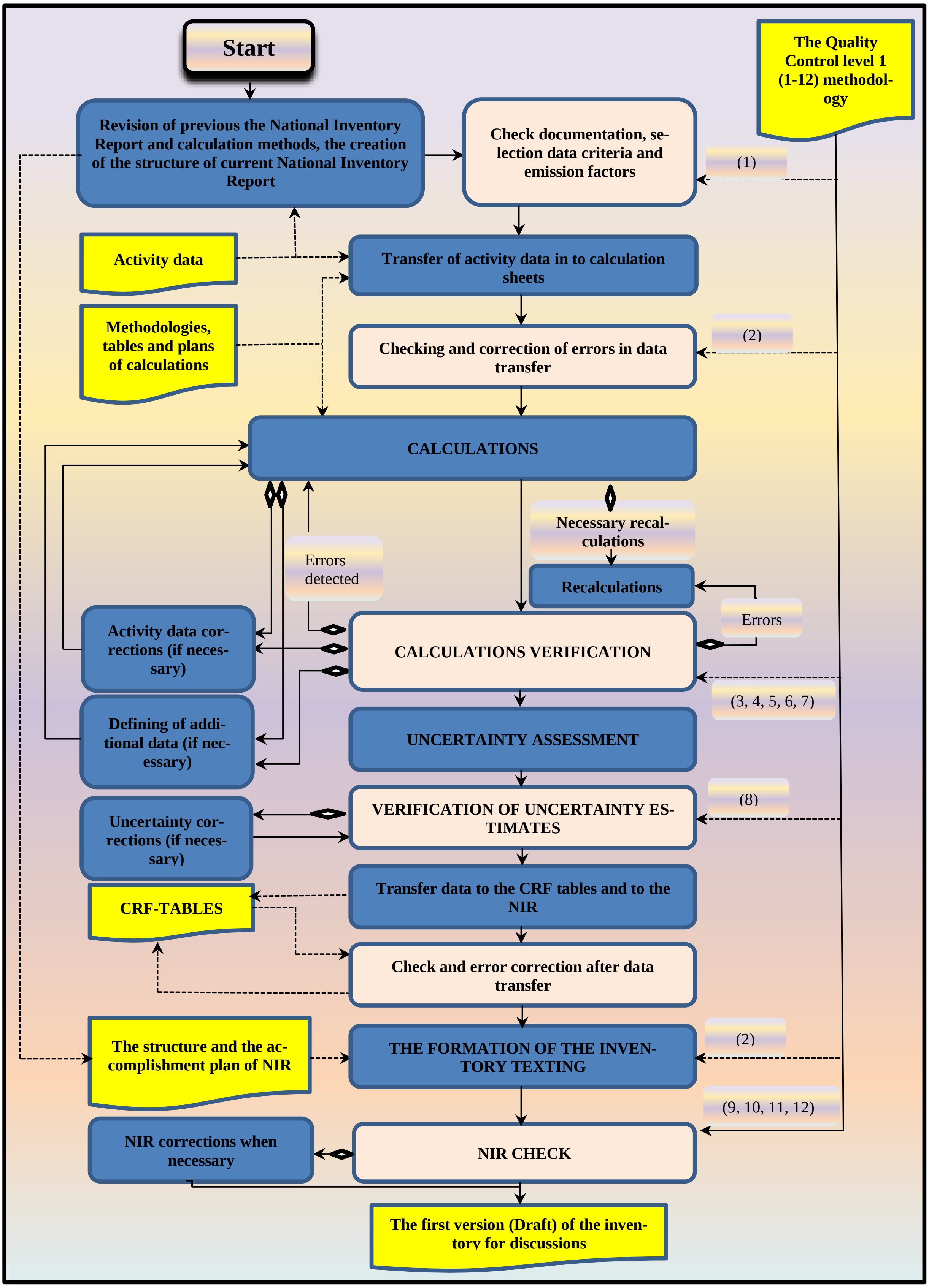

Figure 1.12. Diagram of general development and QC processes

QC procedures were carried out during preparation of the NIR by its developers, involving, if necessary, experts from other organizations for consultancy and required additional information. Within the framework of QC the approved reporting forms were used in the form of reports, notices and electronic files (tables).

Sector experts have carried out the main part of QC procedures, particularly comprehensive checks of source data, emissions factors, calculations, completeness of documentation etc. The entity responsible for QA/QC inspected general trends, compliance with the methodologies used, etc.

Sectoral experts also carried out detailed checks for specific source categories (Tier 2), especially for the key ones, namely:

1) comparison of activity data, emission factors and volumes for the entire time series. Major changes were identified and analyzed (more than 5 %) in different data sources, the results using the current and simplified methods, etc.

2) comparison of the results of emission calculation obtained using different approaches (for example, comparison of calculations using the «top down» and «bottom up» approaches in the in the categories 1.A.3.a Domestic aviation, 1.D.1.a International aviation in the Energy sector);

3) assessment of applicability of 2006 IPCC default factors to the national circumstances;

4) comparison of national emission factors and 2006 IPCC default factors and definition of the specific national conditions that result in discrepancies in the coefficients;

5) comparison of the data with those of the previous year and time-series trends;

6) comparison of data from different sources, especially for the categories with high levels of uncertainty. A comparison was made with data from international or foreign sources in the absence of alternative data at the national level.

Improvements in quality control area

Planned improvements of the QC system are associated with implementation of MS ISO 9000.

Particular attention is given to activities aimed at improving the existing estimation and quality control techniques if discrepancies detected in after checks performed. Fig. 1.13 shows a diagram of the process of analyzing check findings, searching for causes of detected inconsistencies, found errors fixing and reviewing action plans, in particular related to the need to plan and implement corrections of control or calculation techniques, as well as other corrective and preventive actions (for example, checking calculation results in terms of MS ISO 9000 terminology).

In this diagram, the following aspects are considered:

– the methodology and results of the calculations are subject to check;

– check is performed using a specific method;

– found inconsistency requires further analysis – it is possible that that is caused by defects of the check method;

– if existence of discrepancies in calculation results is confirmed, in addition to correction of the calculation results, a search for causes of the detected inconsistencies is initiated;

– causes of inconsistencies of calculation results can vary, for example, the calculation method used may be imperfect, negligence or lack of qualification of the executor. Inconsistency may also result from a combination of causes;

– in the case of proved detection of discrepancies, it makes sense to analyze whether these causes have not resulted in other, so far hidden, negative consequences;

– analysis results form the basis for development of the so-called corrective or preventive actions, which, if requiring substantial resources and time to implement them, may results in amendments to the action plan.

Methodologies of control operations must be compliant with methods of basic technological operations (data conversion, calculation, report generation), the results and the process of their preparation being subject to inspection for control operations.

The outcome of control operations is the conclusion on sufficient quality of the primary operation controlled or description of inconsistencies found between the audited operations and requirements placed upon them.

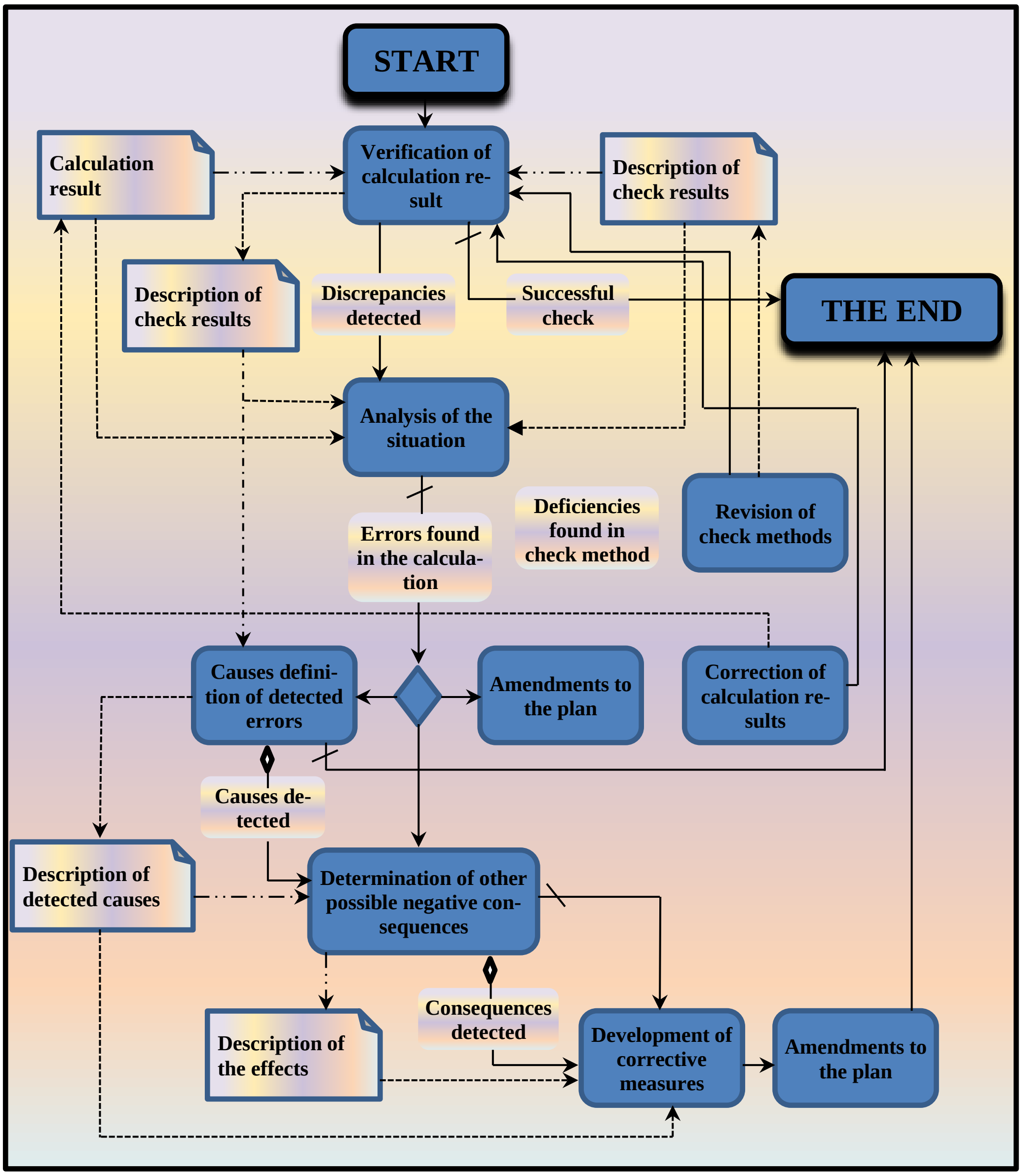

Figure 1.13. The diagram of the check result of analysis process

In case of detection of such discrepancies, the situation should be analyzed and make sure it is not due to possible drawbacks in the check methodology. If such drawbacks are observed, it is necessary to correct the defective control techniques and to repeat this control operation.

Emergence of inconsistencies may be random or non-random. The fact that appearance of inconsistencies may be non-coincidental determines the need of search and identification of their causes.

The identified reason that resulted in the specific inconsistencies found within this technological step may result in similar discrepancies in other similar technological operations, most often this is due to errors in method descriptions or to the tools of realization of the key technological operations that are performed repeatedly. This makes it necessary to conduct pre-emptive targeted search and elimination of such inconsistencies in the similar technological operations results of which have not yet been subject to checks, which may significantly increase effectiveness of the quality control system.

With consideration of abovementioned, within an advanced quality control technique, response to identified inconsistencies may include:

1) analytical work to search for causes of detected discrepancies and their possible further consequences;

2) development and implementation of measures to eliminate detected nonconformities and normalize the process of executing the activities, which in MS ISO 9000 are referred to corrective actions;

3) in the case of identifying possible potential inconsistencies, response to them should include development and implementation of appropriate measures, which in MS ISO 9000 are referred to preventive actions.

1.2.3.3 Quality assurance (validation, verification)

QA procedures provides an independent expert peer review of the level 1 or conducting more extensive independent expert review or audits as additional QA procedures corresponding to the level 2, within the available resources.

QA was carried out by the involvement of the central executive authorities, organizations, institutions and independent experts with the aim of obtaining review reports, expert judgements, feedback to the inventory as a whole and separate categories.

Among involved in the QA process executors (participants) should be highlighted:

- Secretariat of the Cabinet of Ministers of Ukraine;
- Verkhovna Rada Committee for Environmental Policy, Environmental Management;
- National Security and Defense Council of Ukraine;
- Ministry of Economy of Ukraine;
- Ministry of Energy of Ukraine;
- Ministry of Health of Ukraine;
- Ministry of Foreign Affairs of Ukraine;
- Ministry of Finance of Ukraine;
- Ministry of Communities, Territories and Infrastructure Development of Ukraine (hereinafter – MCTIDU);
- Ministry of Education and Science of Ukraine;
- State Customs Service;
- State Service of Ukraine for Geodesy, Cartography and Cadastre (hereinafter –StateGeoCadastre);
- State Statistics Service of Ukraine;
- State Agency on Energy Efficiency and Energy Saving of Ukraine;
- State Forest Resources Agency of Ukraine;
- National Academy of Sciences of Ukraine (hereinafter – NASU);
- State Water Resources Agency of Ukraine;
- State Emergency Service of Ukraine;
- Ukrainian Hydrometeorological Institute of National Academy of Sciences and State Emergency Service of Ukraine;
- Public Organization «Bureau of complex analysis and forecasts «BIAF»;
- Institute of General Energy of NASU;
- State Enterprise "The State Road Transport Research Institute" (hereinafter – SE "DergavtotransNDIproect") of MCTIDU;
- State Enterprise «Ukrainian Research & Technology Center of Metallurgy Industry «Energostal» (SE «UkrRTC «Energostal»);
- State Enterprise «Cherkassy State Research Institute for technical and economic information in chemical industry»;
- Institute of Animal biology of National Academy of Agrarian Sciences of Ukraine (hereinafter – NAASU);
- Institute of Animal Science of NAASU;
- Thermal Energy Technology Institute of NASU;
- National Scientific Centre «Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine»;
- Ukrainian Order "Sign of Honour" Research Institute of Forestry and Forest Melioration named after G.M. Vysotsky (hereinafter – URIFFM);
- Scientific Engineering Centre "Biomass" Ltd. (hereinafter – SECB).

External review

Independent external review of the National Inventory Report is generally seen in the framework of Tier 1 Quality Assurance procedures. In preparation of the GHG inventory, external review is performed in two stages:

1) At the first stage, developers come up with a draft of the NIR, which is placed on the MEPR website (https://mepr.gov.ua) for public discussion with all interested organizations and individuals. Additionally a notice with a link to the draft NIR is sent to the relevant ministries and entities, to leading experts in the field of GHG inventory for delivery their comments and suggestions.

2) At the second stage, after the NIR's update to consider the comments received during the public discussion, specialized research organizations and independent experts in the respective sectors are involved for external review of the used activity data, emission factors and calculation methods of GHG inventory in key categories that received significant recommendations during inventory preparation in previous years and in the current year. The set of documents submitted for review, in addition to the current version of the NIR, includes Excel sheets with GHG emission and removals. Moreover, the current estimates of emissions by sectors, if possible, are presented and discussed at various seminars and conferences, as an additional step of external review.

The following describes the results of QA performed for categories of the National Inventory Report. **Under development.**

The Energy sector.

The Industrial processes and product use sector.

The Agriculture sector.

The Land Use, Land-Use Change and Forestry sector.

Inter-Agency Commission of Climate Change and Ozone Layer Protection

The Inter-Agency Commission of Climate Change and Ozone Layer Protection (hereinafter – IAC) was established by Resolution of the Cabinet of Ministers of Ukraine in September 23, 2020 No. 879 to organize development and coordination of implementation of the national strategy and national action plan for implementation of Ukraine's commitments under the UNFCCC and KP, Paris Agreement, Vienna Convention for the Protection of the Ozone Layer, Montreal Protocol on Substances that Deplete the Ozone Layer and etc.

The key tasks of IAC include the preparation of proposals for the implementation of state policy of climate change and ozone layer protection; identification of ways and mechanisms of solving problematic, issues that aroused during the implementation of state policy of climate change and ozone layer protection; etc.

In accordance with the assigned tasks, the Commission carries out work organization and proposals consideration for implementation of climate change and ozone layer protection issues of state policy; coordination of central executive institutions, regarding development of the project plans and national targeted programs for adaptation to climate change; consideration of reporting and other documents to be submitted to the UNFCCC Secretariat, Ozone Secretariat (Secretariat for the Vienna Convention for the Protection of the Ozone Layer) and Montreal Protocol on Substances that Deplete the Ozone Layer, etc.

According to the existing legal document, namely Resolution of the Cabinet of Ministers of Ukraine in September 23, 2020 No. 879 the IAC includes Chairman of the Commission, First Deputy Chairman of the Commission, Deputy Chairman of the Commission, Secretary of the Commission and other Commission members. The Cabinet of Ministers of Ukraine approves the Commission Staff. The Chairman of the Commission approves its personnel and make necessary changes to it.

The IAC shall include:

– Ministry of Environmental Protection and Natural Resources – Chairman of the Commission;

– Deputy Minister for Development of Economy, Trade and Agriculture of Ukraine – First deputy Chairman of the Commission;

– Deputy Minister of Environmental Protection and Natural Resources for European Integration – Deputy Chairman of the Commission;

– head of the profile structural unit of the MEPR – Secretary of the Commission;

– Deputy Minister of health of Ukraine;
– Deputy Minister of Foreign Affairs of Ukraine;
– Deputy Minister of Finance of Ukraine;
– Deputy Minister of Infrastructure of Ukraine;
– Deputy Minister of Education and Science of Ukraine;
– Deputy Minister for Communities and Territories Development of Ukraine;
– Deputy Minister of Energy of Ukraine for European Integration;
– Deputy Chairman of the State Customs Service;
– Deputy Chairman of the State Service of Ukraine for Geodesy, Cartography and Cadastre of Ukraine;
– Deputy Chairman of the State Statistic Service of Ukraine;
– Chairman of the State Agency on Energy Efficiency and Energy Saving of Ukraine;
– First deputy Chairman of the State Forest Resources Agency of Ukraine;
– Chairman of the Verkhovna Rada Committee for Environmental Policy, Environmental Management (if agreed);
– People's Deputies of Ukraine
– representative of the staff of the National Security and Defense Council of Ukraine (if agreed);
– representative of the Secretariat of the Cabinet of Ministers of Ukraine.

According to the current Ukrainian regulations and procedures, the NIR is finalized with consideration of the recommendations obtained from external review, including in the process of public discussion. The NIR submits to the IAC for its final approval. Based on the decision adopted by the IAC, the MEPR submits the official NIR and CRF tables to the UNFCCC Secretariat.

1.2.3.4 Confidential information handling

In accordance with the Law of Ukraine from September 17, 1992 of No. 2614-XII «About the State Statistics», spreading of information on the basis of which it is possible to figure out confidential information about an individual respondent, as well as any information that allows to indirectly identify confidential information about an individual respondent is prohibited. Therefore, some statistical data on goods produced at fewer than three companies, as well as data on GHG emissions in production of various types of products data on whose activities are confidential and for which default emission factors are applied for GHG inventory are not separately shown in the NIR. Production of most types of these products in Ukraine leads to precursors emissions or negligible GHG emissions. The categories that include production of these types of products are not key ones and are in the sector IPPU (CRF Sector 2), therefore, for estimating emissions in these categories, mostly default emission factors are used.

To reflect GHG emissions in categories for which activity data is considered as confidential information, the following methods were used in preparation of the inventory:

➢ merging of emissions as categories belonging to the same group (for example, combining emissions of CO_2 from production of calcium carbide and silicon carbide, combining emissions in the category 2.B.8 Petrochemical and Carbon Black Production;

➢ using information obtained from public sources;

➢ using information obtained directly from enterprises;

➢ using estimated activity data;

➢ using default emission factors.

As a result of applying the latter four methods, in this NIR it was possible to significantly reduce the number categories GHG emission in which were previously merged. Thus, GHG emissions are merged in only two cases:

➢ in production of calcium carbide and silicon carbide (data on CO_2 emissions data are presented in category 2.B.5 Carbide Production);

➢ in production of ethylene, polystyrene, propylene, polyethylene, and polypropylene in category 2.B.8 Petrochemical and Carbon Black Production;

- in production of aluminium in category 2.C.3 Aluminium production;
- in production of zinc in category 2.C.6 Zinc production.

During the technical review of the National Inventory Report, Ukraine presents data on activities, emission factors and GHG emissions in the categories that Ukraine considers as confidential information in accordance with the procedure referred to in the Code of Practice for the Treatment of Confidential Information in the Technical Review of Greenhouse Gas Inventories of Parties to Annex I of the Convention (Annex II to Resolution 12/CP.9).

1.2.4 Changes in the National Inventory System

As it has been repeatedly pointed out above, currently under par. 2 of Resolution of the Cabinet of Ministers of Ukraine of May 27, 2020 No. 425 «Some Issues of Optimization of the System of Central Executive Government Bodies», the decision was made to create MEPR.

According to par. 1 and subparagraphs 3.1, 3.2, 4.57-4.62 of Resolution of the Cabinet of Ministers of Ukraine of June, 25, 2020 No. 614 «Some issues of Ministry of Environmental Protection and Natural Resources of Ukraine», the central executive body responsible for preparation, approval, and submission to the UNFCCC Secretariat of information on implementation of Decisions of the Conference of Parties of the UNFCCC and Meetings of the KP Parties and Paris Agreement is the MEPR, which is guided and coordinated by the Cabinet of Ministers of Ukraine. One of the structural units of the MEPR is the Department of Climate Policy and Ozone Layer Protection, the MEPR of July 08, 2020 (subsequently, of August 29, 2022), which has been assigned as responsible for the preparation of the National inventory of anthropogenic GHG emissions and removals.

Moreover, within its assigned tasks, the MEPR is responsible for inventory of anthropogenic GHG emissions by sources and removals by sinks at the national level in order to prepare the NIR, as well as its approval and submission to the UNFCCC Secretariat.

1.3 Inventory preparation

1.3.1 The basic stages of the inventory

The process of preparation of the NIR includes the basic stages:

1. Determining information needs to comply with the methodological requirements stipulated by 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
2. Preparation and sending of information queries to select data sources using official correspondence, telephone, and e-mail.
3. Identification of potential data sources, including organizations and independent experts.
4. Preparation and sending special queries and follow-up work on sources, including contracts for consulting services.
5. Obtaining information, its check to establish completeness and compliance with the query form. Analysis of the information obtained on the possibility of its immediate use for calculation of emissions and reductions.
6. Investigation of anomaly discrepancies in the data appeared through sharp changes in the time series of activity data or significant deviations compared to previous inventories. Clarification of data provided as a response to additional queries and receiving consultations from experts on issues of National Inventory Report preparation.
7. Preparation of information to be used in the calculations.
8. Conducting calculations to determine GHG emissions and removals.
9. Elimination of errors and omissions in the calculations.
10. Preparation of a preliminary version of the NIR (draft of NIR) in accordance with regard to format of the revised "Guidelines on Preparation of National Communications of the Parties included in Annex I to the Convention, Part I: UNFCCC guidelines for reporting annual greenhouse gas inventories" (FCCC/CP/2013/10/Add.3).

11. Upload of the draft National Inventory Report on the website of the MEPR and to obtain comments and suggestions from stakeholders and independent experts.
12. Further development of the draft NIR with regard to comments received.
13. Preparation of the final version of the NIR.
14. Provision of the NIR for consideration of the IAC.
15. Submission of the NIR by the MEPR to the UNFCCC Secretariat.
16. Documentation and archiving of all data used in preparation of the NIR.

1.3.2 Planning and control of activities on greenhouse gas inventory and report development

Annual development and support of the NIR are considered as a separate project, an important aspect of management of which is planning.

The annual plan of development of the NIR is a dynamic information object, in which it is possible to consider changes from year to year in the structure of the following NIR and within the work on its development, and to monitor and, if necessary, quickly adjust the course of actual preparation process of the next NIR.

In line with the information presented paragraph 1.2.3.1 "QA/QC procedures", planning development of the NIR to be submitted in 2023 is covered in internal use documents based on typical annual inventory preparation plans and inventory QA and QC activities, namely:

1) 2022-2023 Action Plan to prepare generalized data on GHG emissions on the territory of Ukraine for the National Inventory Report of Anthropogenic GHG Emissions by Sources and Removals by Sinks in Ukraine for the period of 1990-2021 (submitted in 2023);

2) 2021-2023 QA/QC Action Plan when preparing generalized data on GHG emissions on the territory of Ukraine for the National Inventory Report of Anthropogenic GHG Emissions and Removals by Sinks in Ukraine for the period of 1990-2021 (submitted in 2023).

These documents have framework feature, being designed to serve for high-level project management, and is presented in the form of a consolidated schedule, which allows you to include the desired combination of the three types of works:

– core work on development of intermediate or final results (data);
– control work on checks on compliance between the processes on performing basic operations and their results and methodological and regulatory requirements;
– corrective works to remove detected discrepancies in intermediate or final results of core work and, if necessary, adjustment of the work plan in real time.

1.4 Brief general description of methodologies and data sources used

A detailed description of methodological approaches that were used for estimating GHG emissions and removals is described in the relevant sections of this report. Estimates GHG and precursor emissions were performed using the first, second, and third level approaches. Thus, volumes of emissions in key categories were determined mostly using second-level approaches.

Table 1.2 presents generalized information about assessment methods for estimation of GHG emissions and removals in this inventory.

Table 1.2. Generalized information about assessment methods for estimation of GHG emissions and removals

CRF category	Name of the emission category	Comment on the method applied
1.A	Fuel Combustion Activities	T1, T2, T3
1.A.1	Energy Industries	T1, T2, T3
1.A.2	Manufacturing Industries and Construction	T1, T2
1.A.3	Transport	T1, T2, T3

CRF category	Name of the emission category	Comment on the method applied
1.A.4	Other sectors	T1, T2
1.A.5	Other (not elsewhere specified)	T1
1.B	Fugitive Emissions from Fuels	CS, T1, T2, T3
1.B.1	Solid Fuels	CS, T1, T2, T3
1.B.2	Oil and natural gas and other emissions from energy production	T1, T2
1.C	CO_2 Transport and storage	The category is not calculated
2.A	Mineral industry	T1, T2, T3
2.B	Chemical Industry	T1, T2, T3, EMEP/EEA
2.C	Metal Industry	T1, T3, EMEP/EEA
2.D	Non-energy products from fuels and solvent use	T1, EMEP/EEA
2.E	Electronics industry	The category is not calculated
2.F	Product uses as substitutes for ODS	T1a, T1, T2
2.G	Other product manufacture and use	CS, T2,T3
2.H	Other	EMEP/EEA
3.A	Enteric Fermentation	T1, T2
3.B	Manure management	CS, T1, T2
3.C	Rice Cultivation	T1
3.D	Agricultural Soils	CS, T1, T2
3.E	Prescribed burning of savannas	The category is not calculated
3.F	Field burning of agricultural residues	The category is not calculated*
3.G	Liming	T1
3.H	Urea Application	T1
4.A	Forest Land	CS, T1, T2
4.B	Cropland	CS, T1, T3
4.C	Grassland	CS, T1, T3
4.D	Wetlands	T1
4.E	Settlements	T1
4.F	Other Land	T1
4.G	Harvested Wood Products	T1
4.H	Other	The category is not calculated
5.A	Solid waste disposal	T3
5.B	Biological Treatment of Solid Waste	T1
5.C	Incineration and open burning of waste	T1, T2
5.D	Wastewater Treatment and Discharge	CS, T1, T2
5.E	Other	The category is not calculated

Legend:
T1, T2, T3 – Tiers 1, 2, and 3, respectively, according to 2006 IPCC
M – model-based methodology
CS – national methodology
EMEP/CORINAIR – methodology for GHG inventory

* The Burning of agricultural residues in Ukraine is prohibited under the Code of Administrative Offenses (Art. 77-1) and the Law of Ukraine On Air Protection (Art. 16, 22). Fires that occur in agricultural areas are defined as natural fires (wild fires). Therefore, the emissions from them accounted for in LULUCF.

Table 1.3 indicates the key sources of information from which activity data for calculation of GHG emissions and removals was obtained.

Table 1.3. Summary of the key sources of activity data for estimating GHG emissions and removals

Name of the data source	Name of the activity data
State Statistics Service of Ukraine	Amount of fuel consumed. Calorific value of the key fuels. Volume of production, import, export, and changes in fuel stocks. Volume of oil and natural gas transportation through main oil and gas pipelines. Production, import, and export of industrial products. Livestock by species and sex and age groups in agricultural enterprises and households by regions. Consumption of feed by cows, gender and bulls, and other cattle in agricultural enterprises and households in Ukraine by regions. Milk yield of cows and sheep. Amount of wool produced per sheep. Gross harvesting, yield, and total harvested area of agricultural crops.

Name of the data source	Name of the activity data
	Amount of nitrogen and organic fertilizers applied into the soil in Ukraine by regions. Grouping of agricultural enterprises by presence of livestock. Volume of timber harvesting. Production, import, and export of harvested wood products Disturbance areas in the forests of Ukraine. Statistical reporting form No. 1 – waste "Waste Management" (amount of 1st - 4th class of hazard waste, including industrial organic waste at solid municipal waste landfills). Average annual consumption of food products by population of Ukraine.
Ministry of Energy of Ukraine	Information about the coal industry of Ukraine. Information about the oil and gas system of Ukraine. Information on methane recovery from landfills. Information on the morphology and density of waste. Information on household wastewater. Information on the volumes of activities performed during the period starting from 1990, which falls under the activities of paragraphs 3 and 4, Article 3 of Kyoto Protocol.
State Customs Service	Imports and exports of products containing hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.
State Institution "Center of medical statistics of Ministry of health of Ukraine"	Information on the number of surgeries performed in Ukraine.
Ministry of Defense of Ukraine	Information on fuel consumption for the needs of the Ministry of Defense. Information on the volumes of activities performed during the period starting from 1990, which falls under the activities of paragraphs 3 and 4, Article 3 of Kyoto Protocol.
Energy generation companies	Technical and economic indicators of activity of condensing thermal power plants.
JSC "Naftogaz of Ukraine"	Information about the oil and gas system of Ukraine.
Ukrainian State Air Traffic Services Enterprise (SE "Ukraeroruh")	Aircraft departures information (database).
Industrial enterprises	Data of mineral, chemical and metallurgy, cement, ceramics, glass production, as well as data on use of hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.
Ministry of Communities, Territories and Infrastructure Development of Ukraine	Statistical reporting form No.1-TPV "Report on Solid Waste Management". Information on the implementation of modern methods and technologies in the field of household waste management in Ukraine. Information on the volumes of activities performed during the period starting from 1990, which falls under the activities of paragraphs 3 and 4, Article 3 of Kyoto Protocol.
State Water Resources Agency of Ukraine	Statistical form No. 2-TP "Report on Water Use" (data on volumes of treated household and industrial wastewater). Data on the area of cultivated peat soils.
State Service of Ukraine for Geodesy, Cartography and Cadastre of Ukraine	Information on areas of land use.
State Forest Resources Agency of Ukraine	Information on the volumes of activities performed during the period starting from 1990, which falls under the activities of paragraphs 3 and 4, Article 3 of Kyoto Protocol. Information about forests and forest management activities in the forests of the State Forest Resources Agency of Ukraine. Areas of forest fires in forests of the State Forest Resources Agency of Ukraine.
Territorial Public Administration	Information on the livestock and its structure in agricultural enterprises and household farms, grouping of agricultural enterprises based on the livestock, feed consumption in agricultural enterprises and household farms. Information about technical parameters of existing Municipal Solid Waste landfills and the amount of Municipal Solid Waste deposited. Information about thermal disposal of medical waste..
Regional Departments of the State Emergency Service of Ukraine	Information about the number of fires on agricultural crops by regions.
Institute of Public Administration and Research in Civil Protection	Data on fire areas on grasslands and non-forest wetlands.
State Enterprise «Agency of Animal Identification and Registration»	Data on the livestock of rams and wethers in the sheep herd structure by agricultural enterprises and household farms.
State Agency of Ukraine on the Exclusion Zone Management	Data on forest land in the exclusion zone. Information on the volumes of activities performed during the period starting from 1990, which falls under the activities of paragraphs 3 and 4, Article 3 of Kyoto Protocol.
Ukrainian State-owned Project Forestry Production Association «UKRDERZHLISPROEKT»	Information about forests in the forests of the State Forest Resources Agency of Ukraine and some other forest users.
Companies for methane recovery at the landfills	Data on the methane recovery at the MSW landfills.

1.5 Brief description of key categories

In accordance with the requirements of the 2006 IPCC Guidelines, key categories analysis was performed. The assessment is based on Tier 1 approach, which includes analysis of the emission level and trends. The results of key category analysis for 2019 with and without the LULUCF sector are presented in Tables 1.4 and 1.5, respectively. A detailed analysis of the key categories is presented in Annex 1.

Table 1.4. Key category analysis, excluding LULUCF sector (2021)

IPCC source category	Gas	Level	Trend
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	+	+
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2		+
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	+	+
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	+	+
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	+	+
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2		+
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	+	+
1.A.3.b Road Transportation	CO_2	+	+
1.A.3.d Domestic Navigation - Liquid Fuels	CO_2		+
1.A.3.e Other Transportation	CO_2	+	+
1.A.4 Other Sectors - Gaseous Fuels	CO_2	+	+
1.A.4 Other Sectors - Liquid Fuels	CO_2		+
1.A.4 Other Sectors - Solid Fuels	CO_2		+
1.B.1 Fugitive emissions from Solid Fuels	CH_4	+	+
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CO_2	+	
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	+	+
2.A.1 Cement Production	CO_2	+	+
2.A.2 Lime Production	CO_2	+	
2.B.1 Ammonia Production	CO_2	+	
2.B.2 Nitric Acid Production	N_2O	+	
2.B.8 Petrochemical and Carbon Black Production	CH_4	+	+
2.C.1 Iron and Steel Production	CO_2	+	+
2.C.2 Ferroalloys Production	CO_2	+	
2.F.1 Refrigeration and Air conditioning	HFC		+
3.A Enteric Fermentation	CH_4	+	+
3.D.1 Direct N2O Emissions From Managed Soils	N_2O	+	+
3.D.2 Indirect N2O Emissions From Managed Soils	N_2O	+	+
5.A Solid Waste Disposal	CH_4	+	+
5.D Wastewater Treatment and Discharge	CH_4	+	+

Table 1.5. Key category analysis, including LULUCF sector (2021)

IPCC source category	Gas	Level	Trend
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	+	+
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2		+
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	+	+
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	+	+
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	+	+
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2		+
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	+	+
1.A.3.b Road Transportation	CO_2	+	+
1.A.3.e Other Transportation	CO_2	+	+
1.A.4 Other Sectors - Gaseous Fuels	CO_2	+	+
1.A.4 Other Sectors - Liquid Fuels	CO_2		+
1.A.4 Other Sectors - Solid Fuels	CO_2		+
1.B.1 Fugitive emissions from Solid Fuels	CH_4	+	+
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CO_2	+	
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	+	+
2.A.1 Cement Production	CO_2	+	
2.A.2 Lime Production	CO_2	+	
2.B.1 Ammonia Production	CO_2	+	
2.B.2 Nitric Acid Production	N_2O	+	
2.B.8 Petrochemical and Carbon Black Production	CH_4	+	+
2.C.1 Iron and Steel Production	CO_2	+	+

IPCC source category	Gas	Level	Trend
2.C.2 Ferroalloys Production	CO_2	+	
2.F.1 Refrigeration and Air conditioning	HFC		+
3.A Enteric Fermentation	CH_4	+	+
3.D.1 Direct N2O Emissions From Managed Soils	N_2O	+	+
3.D.2 Indirect N2O Emissions From Managed Soils	N_2O	+	+
4.A.1 Forest Land Remaining Forest Land	CO_2	+	+
4.B.1 Cropland Remaining Cropland	CO_2	+	+
4.C.1 Grassland Remaining Grassland	CO_2		+
4.D.1.1 Peat Extraction Remaining Peat Extraction	CO_2		+
4.E.2 Land Converted to Settlements	CO_2		+
4.G Harvested Wood Products	CO_2	+	
5.A Solid Waste Disposal	CH_4	+	+
5.D Wastewater Treatment and Discharge	CH_4	+	+

1.6 Evaluation of the total uncertainty of the National Inventory Report, including data on the overall uncertainty for the entire inventory

Under development.

Uncertainty estimate was performed using the first level approach, provided in 2006 IPCC Guidelines.

The results indicate that the net emissions in **1990** year including the sector Land use, land-use change and forestry (LULUCF) is 911401.13 kt CO_2 equivalent with an uncertainty of 4.44 %; excluding the LULUCF sector – 942807.63kt CO_2 equivalent with an uncertainty of 3.71 %.

The results indicate that the net emissions in **2021** year including the sector Land use, land-use change and forestry (LULUCF) is 341511.54 kt CO_2 equivalent with an uncertainty of 16.21 %; excluding the LULUCF sector – 327281.18 kt CO_2 equivalent with an uncertainty of 9.11 %.

Based on totals of years 1990 and 2021, the average trend including the LULUCF sector is 62.53 % reduction of emissions; excluding the LULUCF sector – 65.29 % reduction of emissions. The uncertainty of the trend including the LULUCF sector is 5.79 %; excluding the LULUCF sector – 2.62 %.

For more detailed information see Tables A7.1-A7.2 of Annex 7. Uncertainty analysis for the base 1990 year see Tables A7.3-A7.4 of Annex 7 too.

Summary data characterizing the uncertainty with the inventory by sector is shown below, in Tables 1.7 and 1.8 respectively.

Table 1.7. The uncertainty of the inventory by main sectors (including LULUCF)

Sector	Share in total emissions for 1990, %	Share in total emissions for 2021, %	The percentage uncertainties of the emissions for 1990, %	The percentage uncertainties of the emissions for 2021, %
Energy	79.58	61.42	2.45	4.22
Industrial processes and product use	12.97	17.09	0.53	0.85
Agriculture	9.53	13.77	2.84	7.46
LULUCF	-3.45	4.17	2.24	13.65
Waste	1.37	3.56	0.63	1.42

Table 1.8. The uncertainty of the inventory by main sectors (excluding LULUCF)

Sector	Share in total emissions for 1990, %	Share in total emissions for 2021, %	The percentage uncertainties of the emissions for 1990, %	The percentage uncertainties of the emissions for 2021, %
Energy	76.93	64.09	2.37	4.41
Industrial processes and product use	12.54	17.83	0.51	0.89
Agriculture	9.21	14.37	2.74	7.79
Waste	1.32	3.72	0.61	1.48

The lowest percentage of emissions uncertainty in 2021 year is observed in the Industrial processes and product use sector.

1.7 General assessment of completeness

The total national aggregate of estimated emissions for all gases and categories considered insignificant remains below 0.1 per cent of the national total GHG emissions.

The main reasons for the use of notation key (NE, IE) in the GHG inventory in certain categories, are:

➢ **Methodology absence (NE)**:

- when calculating emissions of carbon dioxide **(CO_2)** in the categories – 1.B.1.a.1.ii Post-Mining Activities, 1.B.1.a.2.i Mining Activities, 1.B.1.a.2.ii Post-Mining Activities, 1.B.2.a.4 Refining / Storage, 1.B.2.a.5 Distribution of Oil Products, 3. Sectors/Totals Agriculture Indirect emissions, 3.G.2 Dolomite $CaMg(CO_3)_2$, 5.C.2.1.a Municipal Solid Waste, 5.C.2.1.b Other (please specify), 5.C.2.2.a Municipal Solid Waste, 5.C.2.2.b Other (please specify);
- when calculating emissions of methane **(CH_4)** in the categories – 1.B.2.a.5 Distribution of Oil Products, 2.B.1 Ammonia Production, 2.B.5.b Calcium Carbide, 4.A Forest Land/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils, 4.B Cropland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils, 4.C Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils, 5.C.2.1.a Municipal Solid Waste, 5.C.2.1.b Other (please specify), 5.C.2.2.a Municipal Solid Waste, 5.C.2.2.b Other (please specify);
- when calculating emissions of nitrous oxide **(N_2O)** in the categories – 1.B.2.a.4 Refining / Storage, 3.B.2.5 Indirect N_2O Emissions, 3.D.1.2.b Sewage Sludge Applied to Soils, 4.A.2.3 Wetlands converted to forest land, 4.D.1 Wetlands Remaining Wet-lands/4(V) Biomass Burning/Wildfires, 5.C.2.1.a Municipal Solid Waste, 5.C.2.1.b Other (please specify), 5.C.2.2.a Municipal Solid Waste, 5.C.2.2.b Other (please specify);
- when calculating emissions of non-methane volatile organic compound **(NMVOC)** in the category 5.C.1 Waste incineration;
- when calculating emissions of nitrogen oxides **(NO_x)** in the category 5.C.1 Waste incineration;
- when calculating emissions of sulphur dioxide **(SO_2)** in the category – 5.C.1 Waste incineration;
- when calculating emissions of carbon monoxide **(CO)** in the category 5.C.1 Waste incineration.

➢ **Included elsewhere (IE):**

- when calculating emissions of carbon dioxide **(CO_2)** in the categories – 1.A.3.b.ii Light duty trucks (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants), 1.A.3.b.iii Heavy duty trucks and buses (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants), 1.A.3.b.iv Motorcycles (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene), 1.A.4.c.ii Off-road vehicles and other machinery (gasoline, diesel oil, liquefied petroleum gases, gaseous fuels, biomass), 1.A.4.c.iii Fishing (residual fuel oil, diesel oil, gasoline, gaseous fuels, biomass), 1.B.2.c.1.ii Gas, 1.B.2.c.1.iii Combined, 1.B.2.c.2.iii Combined, 1.AA Fuel Combustion - Sectoral approach / Information item / (Biomass, Fossil fuels), 1.AD Feedstocks, reductants and other non-energy use of fuels / Liquid fuels / Naphtha, 2.B.5.a Silicon carbide, 2.C.1.d Sinter, 2.C.1.e Pellet, 4.A Forest Land / 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils, 4.B Cropland / 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils, 4.B.2 Land Converted to Cropland/4(V) Biomass Burning/Wildfires, 4.C Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils, 4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Drained, 4.D.2 Land Converted to Wetlands/4(V) Biomass Burning/Wildfires;

- when calculating emissions of methane **(CH_4)** in the categories –1.A.3.b.ii Light duty trucks (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants), 1.A.3.b.iii Heavy duty trucks and buses (biomass, gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, kerosene, lubricants), 1.A.3.b.iv Motorcycles (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene), 1.A.4.c.ii Off-road vehicles and other machinery (gasoline, diesel oil, liquefied petroleum gases, gaseous fuels, biomass), 1.A.4.c.iii Fishing (residual fuel oil, diesel oil, gasoline, gaseous fuels, biomass), 1.AA Fuel Combustion - Sectoral approach / Information item / (Biomass, Fossil fuels), 1.B.2.c.1.ii Gas, 1.B.2.c.1.iii Combined, 1.B.2.c.2.iii Combined, 4.B.2 Land Converted to Cropland/4(V) Biomass Burning/Wildfires, 4.C.2 Land Converted to Grassland/4(V) Biomass Burning/Wildfires, 4.D.2 Land Converted to Wetlands/4(V) Biomass Burning/Wildfires;
- when calculating emissions of nitrous oxide **(N_2O)** in the categories – 1.A.3.b.ii Light duty trucks (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants), 1.A.3.b.iii Heavy duty trucks and buses (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants), 1.A.3.b.iv Motorcycles (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene), 1.A.4.c.ii Off-road vehicles and other machinery (gasoline, diesel oil, liquefied petroleum gases, gaseous fuels, biomass), 1.A.4.c.iii Fishing (residual fuel oil, diesel oil, gasoline, gaseous fuels, biomass), 1.AA Fuel Combustion - Sectoral approach / Information item / (Biomass, Fossil fuels), 1.B.2.c.2.iii Combined, 3.B.2 N_2O and NMVOC Emissions (Pasture, Range, and Paddock), 4.B.2 Land Converted to Cropland/4(V) Biomass Burning/Wildfires, 4.C.2 Land Converted to Grassland/4(V) Biomass Burning/Wildfires, 4.D.2 Land Converted to Wet-lands/4(V) Biomass Burning/Wildfires.

More detailed information is given in table 1 of Annex 5.1.

According to the classification of notation keys given in the UNFCCC reporting guidelines on annual GHG inventories*:

- NO (*Not occurring*) for activities or processes, which within a country do not occur;
- NE (*Not estimated*) for possible GHG emissions by sources and removals by sinks, in respect of which the assessment was not carried out;
- NA *(Not applicable)* for activities in a particular category of source/sink, which does not lead to emissions or removals of a specific gas;
- IE *(Included elsewhere)* for activities or categories of GHG emissions included in the inventory but not presented separately for this category.

* Guidelines for the preparation of national communications by parties included in Annex I to the Convention, part I: Guidelines of the UNFCCC for the submission of reports on annual inventories, FCCC/CP/2002/8

2 TRENDS IN GREENHOUSE GAS EMISSIONS

2.1 Trends in total greenhouse gas emissions by gas

Dynamics of GHG emissions demonstrate the trend, which may be considered in several phases over the period of 1990-2019. During the first phase (1990-1999), a catastrophic decline in GDP and reduction in energy consumption were observed, which led to a decrease in GHG emissions. In the second phase (2000-2007), there was stabilization of the trend and a gradual increase in emissions, which is due to the economic growth (including GDP growth), but there is no direct correlation between the growth in emissions and in GDP. Primarily, this is due to structural changes in the economy, an increased role of trade, services, and the financial sector in comparison with industrial production. During the third phase (2008-2013), GHG emissions depended on the factor of the global financial crisis (2008-2009), which largely affected production volumes in key export-oriented sectors: metallurgy, chemical, machine building, which, in turn, affected other sectors - power generation and mining. In 2014 GHG emissions sharply declined - by about 12 % compared with 2013 with continued trend of decline in 2015 by 13 % compared with 2014. Among the key factors of the sharp drop should be mentioned a occupation and attempted annexation of Crimea and armed aggression by the Russian Federation, what led to a considerable reduction in industrial production, and, as a consequence, reduction in energy consumption[3]. That also led to interruption of supply and trade connections of industries on temporary occupied by the Russian Federation territory of Ukraine with industries of other regions in the country.

Emissions in 2020 was impacted mostly by COVID-19 pandemic and the consequences of restrictions against spread of disease and lower yields of agricultural crops. For example, emissions from transport, which was severely impacted by anti-COVID-19 measures, have fallen by 16 % compared to 2019. Lower yields of agricultural crops together with higher mineral fertilizers application in 2020 resulted in rapid decline of GHG emissions in Cropland category by 45 % compared with 2019.

Emission trends in 2021 in general is characterized by the recovery from the global pandemic and intensification of production in different sectors of the economy of Ukraine. This, in turn, resulted in total increase of emissions by 8.5 % compared with 2020.

Table 2.1 and Fig. 2.1 show a histogram of total emissions of carbon dioxide, methane, and nitrous oxide in Ukraine, including LULUCF sector. The share of PFCs, HFCs, the SF_6 and NF_3 in total emissions amounted to 0.6% in 2021, and NF_3 emissions in Ukraine do not occur.

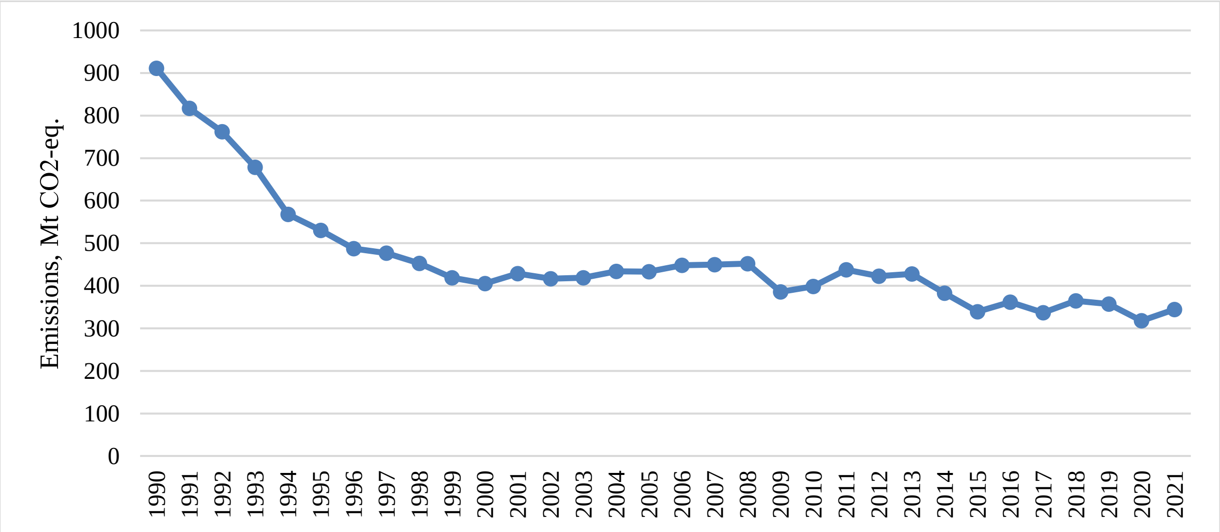

Fig. 2.1. GHG emissions in Ukraine (including LULUCF), Mt CO_2-eq.

[3] On 18 January 2018, the Parliament of Ukraine adopted the law "On the peculiarities of State policy on ensuring Ukraine's State sovereignty over temporarily occupied territories in Donetsk and Luhansk regions", which defines the legal status of certain areas of the Donetsk and Luhansk regions as temporarily occupied territories of Ukraine

Table 2.1. Dynamics of total greenhouse gas emissions in Ukraine (Mt CO_2-eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
CO_2 emissions without net CO_2 from LU-LUCF	706.2	632.9	589.3	510.3	419.5	390.1	351.8	340.5	328.8	298.6	285.7	303.9	295.9
CO_2 emissions with net CO_2 from LULUCF	674.6	593.1	549.7	477.2	382.2	357.6	323.7	317.8	300.4	267.2	262.5	286.2	280.8
CH_4 emissions without CH_4 from LULUCF	182.9	175.0	167.1	158.7	149.3	139.0	135.1	129.7	126.0	127.3	118.3	116.9	109.4
CH_4 emissions with CH_4 from LULUCF	182.9	175.1	167.2	158.7	149.3	139.1	135.1	129.8	126.1	127.3	118.3	116.9	109.4
N_2O emissions without N_2O from LULUCF	53.4	48.3	44.7	41.9	36.0	32.8	28.5	29.2	25.9	23.8	23.8	25.1	25.5
N_2O emissions with N_2O from LULUCF	53.6	48.5	44.9	42.1	36.2	33.1	28.7	29.5	26.2	24.1	24.1	25.4	25.8
HFCs*	NO	NO	NO	NO	NO	NO	NO	6.43	13.02	14.14	15.73	29.05	64.27
PFCs*	235.82	188.20	142.35	143.57	161.22	178.06	143.24	146.99	120.64	101.81	115.74	112.08	98.66
SF_6*	0.01	0.02	0.03	0.06	0.06	0.07	0.07	0.13	0.19	0.31	0.42	0.46	1.07
NF_3*	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	942.8	856.4	801.3	711.1	604.9	562.1	515.4	499.6	480.9	449.8	427.9	446.0	431.0
Total (with LULUCF)	911.4	816.8	762.0	678.3	567.9	530.0	487.7	477.2	452.8	418.8	405.0	428.6	416.2
Total (without LULUCF, with indirect)	942.8	856.4	801.3	711.1	604.9	562.1	515.4	499.6	480.9	449.8	427.9	446.0	431.0
Total (with LULUCF, with indirect)	911.4	816.8	762.0	678.3	567.9	530.0	487.7	477.2	452.8	418.8	405.0	428.6	416.2
Net CO_2 from LULUCF	-31.4	-39.6	-39.3	-32.8	-37.0	-32.1	-27.7	-22.5	-28.1	-31.0	-22.9	-17.4	-14.8

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2 emissions without net CO_2 from LU-LUCF	307.2	310.6	313.5	333.1	336.8	326.0	277.6	294.4	308.4	304.4	297.5	257.6	223.8
CO_2 emissions with net CO_2 from LULUCF	285.7	300.7	304.3	320.7	322.3	326.5	272.5	285.1	316.8	309.2	316.3	277.5	243.3
CH_4 emissions without CH_4 from LULUCF	110.0	106.9	102.8	100.5	100.3	93.5	85.4	84.8	86.2	80.7	75.5	69.0	61.6
CH_4 emissions with CH_4 from LULUCF	110.1	106.9	102.8	100.5	100.4	93.6	85.5	84.9	86.3	80.7	75.5	69.0	61.6
N_2O emissions without N_2O from LULUCF	22.8	25.3	25.6	26.0	25.6	30.8	26.8	27.4	33.3	31.9	35.4	35.3	33.0
N_2O emissions with N_2O from LULUCF	23.1	25.6	25.9	26.3	26.0	31.1	27.1	27.6	33.5	32.1	35.6	35.5	33.2
HFCs*	105.20	187.26	285.07	402.28	561.13	647.25	663.76	743.86	823.17	844.29	891.71	869.10	801.65
PFCs*	77.15	93.34	142.33	111.16	154.71	174.24	53.95	26.67	NO	NO	NO	NO	NO
SF_6*	1.99	3.08	4.47	4.27	5.20	9.34	9.37	9.71	8.42	10.99	12.54	16.73	19.64
NF_3*	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	440.3	443.1	442.4	460.0	463.4	451.2	390.5	407.4	428.8	417.8	409.3	362.8	319.2
Total (with LULUCF)	419.1	433.6	433.5	448.0	449.4	452.0	385.8	398.4	437.4	422.9	428.2	382.9	338.9
Total (without LULUCF, with indirect)	440.3	443.1	442.4	460.0	463.4	451.2	390.5	407.4	428.8	417.8	409.3	362.8	319.2
Total (with LULUCF, with indirect)	419.1	433.6	433.5	448.0	449.4	452.0	385.8	398.4	437.4	422.9	428.2	382.9	338.9
Net CO_2 from LULUCF	-21.3	-9.6	-8.9	-12.0	-14.1	0.8	-4.7	-9.0	8.6	5.0	19.0	20.1	19.7

	2016	2017	2018	2019	2020	2021
CO_2 emissions without net CO_2 from LULUCF	234.0	223.1	231.7	221.9	206.8	213.3
CO_2 emissions with net CO_2 from LULUCF	258.2	236.4	256.4	245.1	205.8	227.3
CH_4 emissions without CH_4 from LULUCF	66.4	64.1	67.9	70.1	71.7	71.6
CH_4 emissions with CH_4 from LULUCF	66.4	64.2	67.9	70.1	72.0	71.6
N_2O emissions without N_2O from LULUCF	36.3	35.0	38.8	40.4	37.7	43.6
N_2O emissions with N_2O from LULUCF	36.5	35.1	39.0	40.6	38.1	43.8
HFCs*	921.37	1049.28	1395.83	1682.97	1747.00	1895.15
PFCs*	NO	NO	NO	NO	NO	NO
SF_6*	24.37	28.56	33.45	38.79	43.35	48.94
NF_3*	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	337.6	323.3	339.8	334.1	318.0	330.4
Total (with LULUCF)	362.0	336.7	364.7	357.5	317.6	344.6
Total (without LULUCF, with indirect)	337.6	323.3	339.8	334.1	318.0	330.4
Total (with LULUCF, with indirect)	362.0	336.7	364.7	357.5	317.6	344.6
Net CO_2 from LULUCF	24.4	13.4	24.9	23.3	-0.4	14.2

*emissions presented in kt CO_2-eq.

2.1.1 Emissions of carbon dioxide

Fig. 2.2 shows a histogram of CO_2 emissions for the time series 1990-2021 in Ukraine. CO_2 emissions with LULUCF in 2021 amounted to 227.14 Mt, what is almost 3 times lower compared with 1990 (674.59 Mt).

CO_2 emissions in the Energy sector in 2021 amounted to 159.74 Mt, what is 73.0 % lower than the value in the base year. In 1990, CO_2 emissions were 592.25 million tons and by 65.6 % consisted of emissions from fuel combustion compared to total emissions in the country. Such structure of CO_2 emissions was due to the high energy intensity of the economy. The economic decline that followed the collapse of the Soviet Union as well as structural changes in the sector and economy led to a significant reduction in energy consumption and CO_2 emission reduction in the energy sector in the period from 1990 to 2021.

Carbon dioxide emissions in IPPU sector in 2021 amounted to 53.14 Mt, what is 52.2 % lower than the value in the base year, but 9.8 % higher than the in 2020. The largest source of CO_2 emissions in the IPPU sector is the Metal industry that amounts to 68 % of total CO_2 emissions in the sector. CO_2 emissions in sector in the period from 1990 to 2021 have decreased significantly due to a reduction in production output caused by the collapse of the USSR.

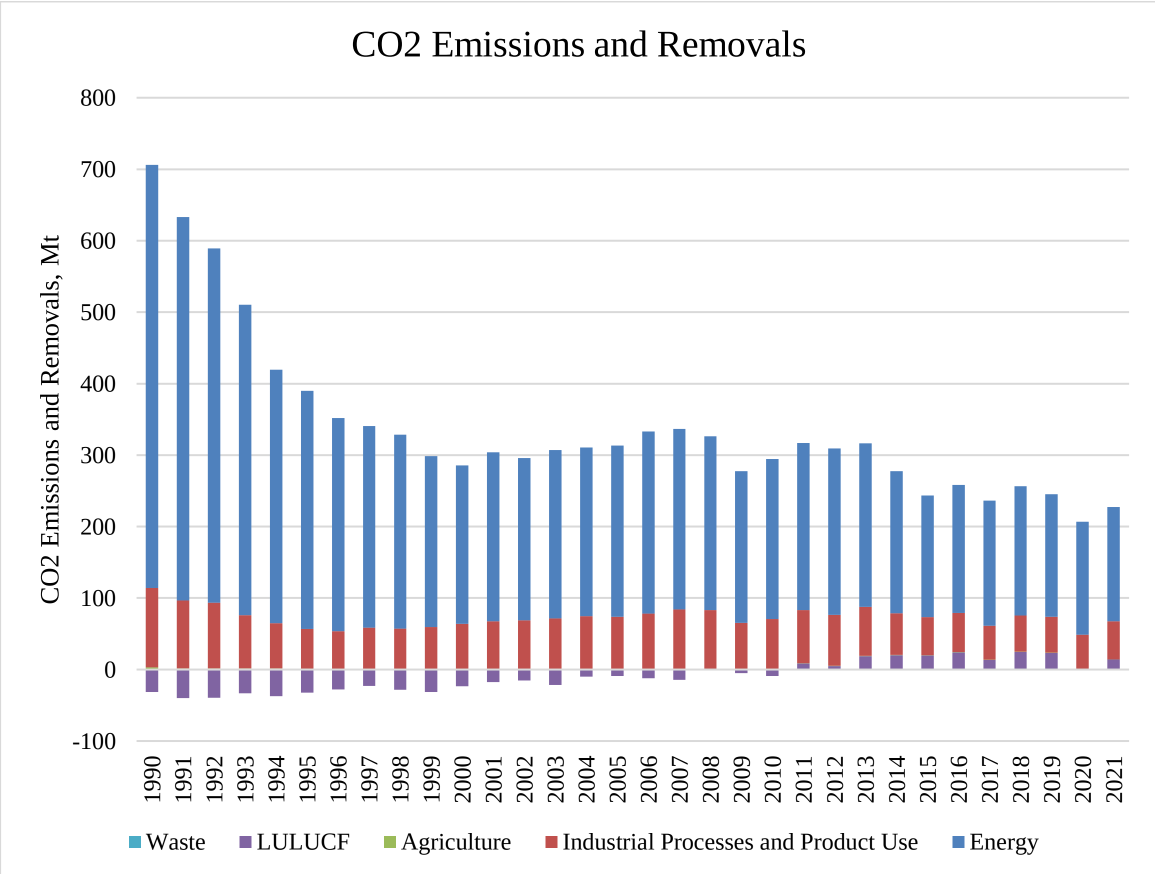

Fig. 2.2. Emissions and sinks of carbon dioxide by sector in Ukraine, Mt

2.1.2 Methane emissions

Emissions of CH_4 are the second largest after CO_2 considering their share in total GHG emissions. In 2021, CH_4 emissions in Ukraine amounted to 71.57 Mt CO_2-eq. Compared to 1990, when the emissions were 182.94 Mt CO_2-eq., the emissions decreased by 60.9 %. In the last reporting year, the most significant source of methane emissions was the Energy sector - 67.7 %, and significant emissions were observed in Agriculture (11.3 %) and Waste (15.5 %) as well.

The largest CH_4 emissions in the Energy sector come from coal mines, as well as from production, transportation, storage, distribution, and consumption of oil and natural gas. Since 1990, emissions in category 1.B Fugitive emissions from fuels decreased by more than 2 times - from 127.47 to 50.36 Mt CO_2-eq.

In agriculture, the main source of CH_4 emissions is cattle enteric fermentation. The economic decline led to reduction in agricultural production, and consequently to reduced methane emissions in the Agriculture sector in 2021 to 324.32 kt, what is more than four times lower than in 1990.

In the Waste sector, the greatest emissions of CH_4 occur during anaerobic decomposition of solid municipal waste, as well as from waste water. Compared to 1990, emissions from solid waste disposal sites increased by 17.8 %, and emissions from waste water decreased by 24.1 %.

Methane emissions in IPPU take place during the production of pig iron, silicon carbide, methanol, carbon black, ethylene, coke, and some other products. The volumes of CH_4 emissions in the sector over the reporting period increased from 48.28 to 155.88 kt (by 222.9 %) due to increase of production volumes. Emissions of CH_4 in the LULUCF occur in very small amounts due to wild-fires and drainage of organic soils (see Fig. 2.3).

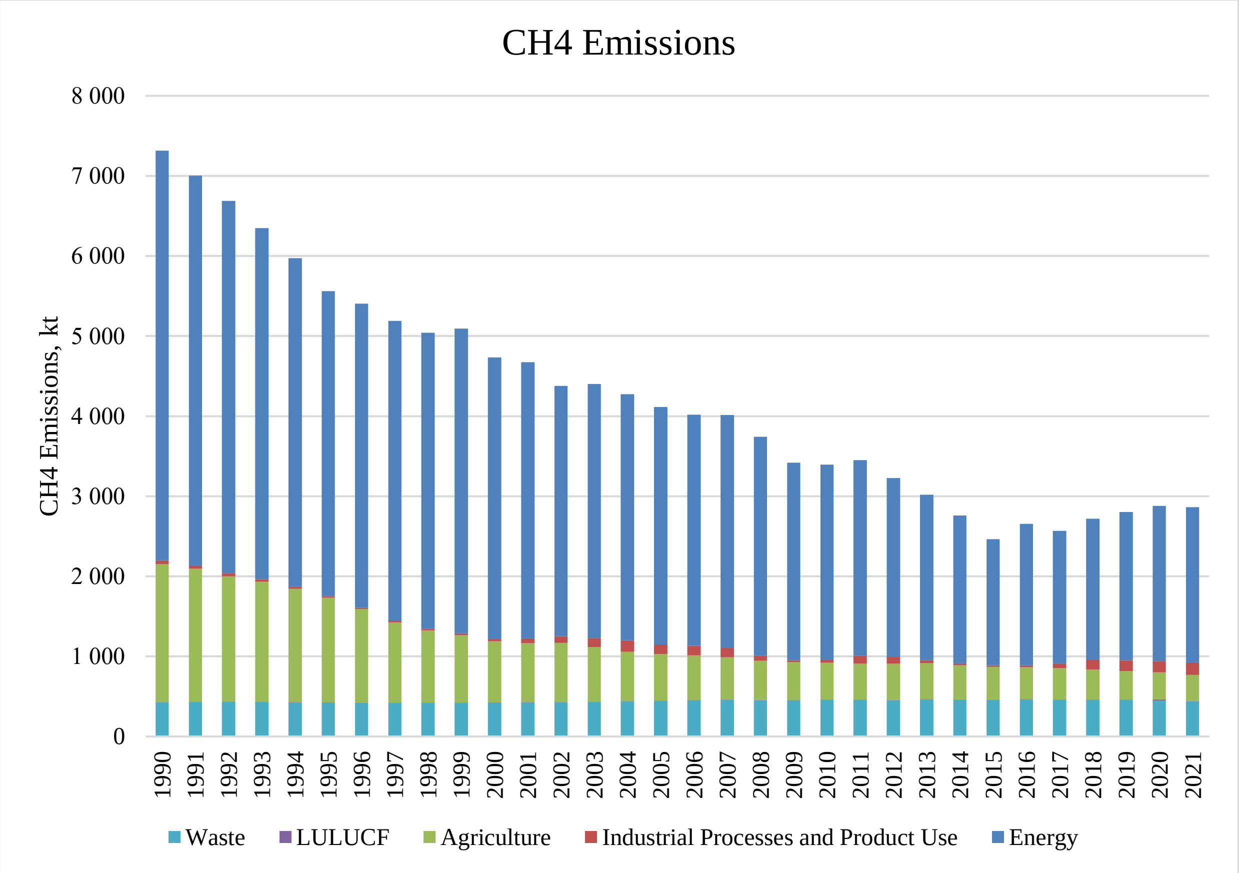

Fig. 2.3. Methane emissions in Ukraine by sector, kt

2.1.3 Emissions of nitrous oxide

Nitrous oxide emissions in Ukraine in 2021 amounted to 43.79 Mt CO_2-eq., which is lower than in 1990 by 18.4 % (53.64 Mt CO_2-eq.). Compared with 2020, emissions of nitrous oxide increased by 15.0 %. The largest source of nitrous oxide emissions in Ukraine, as in the previous submissions, is the Agriculture sector - 87.9 % of total nitrous oxide emissions in 2021. Emissions from this sector occur from agricultural soils and the activities of manure management.

The second largest sector by nitrogen oxide emissions is IPPU sector - 5.7 % of the totals in 2021. The key sources of emissions in this sector are production of nitric and adipic acid, as well as use of nitrous oxide for medical purposes. In the Energy sector emissions of N_2O had a 3.5 % of share in total emissions of the gas.

Moreover, N_2O emissions occur in the Waste sector (2.5 %), as well as small quantities in LULUCF (0.4 %).

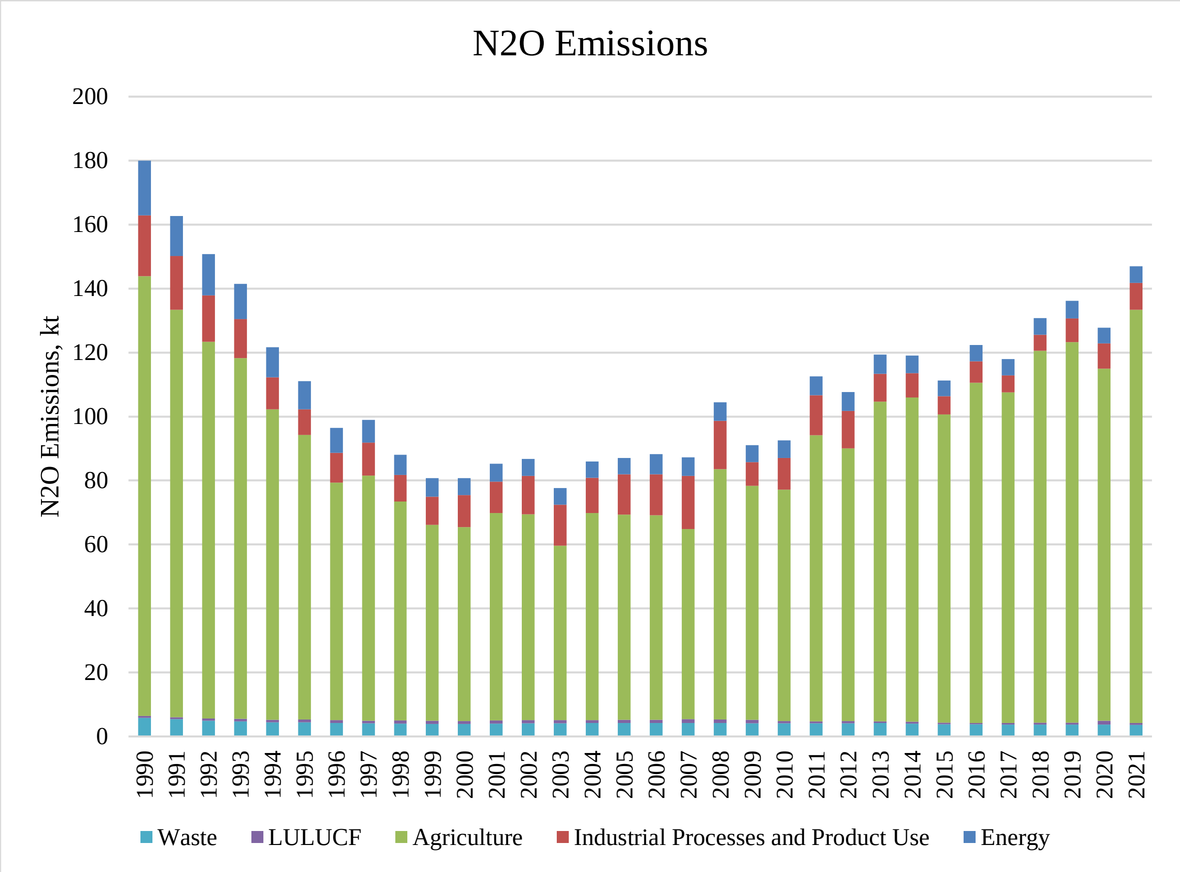

Fig. 2.4. Nitrous oxide emissions in Ukraine by sector, kt

2.1.4 Emissions of hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride

Emissions of HFCs, PFCs, SF_6, and NF_3 in Ukraine are not much significant in terms of volumes in comparison with total GHG emissions (0.6% of the total emissions in 2021). HFCs emissions are associated with production and maintenance of refrigerators, air conditioners, use of fire extinguishing systems, foams and aerosols. PFCs emissions are associated with aluminum production, and emissions of sulfur hexafluoride - with use of gas-insulated high-voltage switches. Fig. 2.6 presents the diagram of HFCs, PFCs, and SF_6 emissions in IPPU sector. From 1990 to 1996 inclusive, there were no HFCs emissions in the country, until 1996 HFCs were not used under these categories. Emissions of PFCs and SF_6 in 1990 amounted to 235.82 and 0.01 kt CO_2-eq. respectively. The sharp increase in HFCs emissions since 2000 is due to the beginning of intensive use of these gases in fire extinguishing and foam materials, and in SF_6 emissions - to an increased number of gas-insulated high-voltage circuit breakers in operation in electric networks of Ukraine. The sharp increase in HFCs emissions in 2017-2019 after the decreasing trend in 2015 – 2016 explains by recovery of economy of Ukraine from previous declines that resulted in growth of import of HFCs-contained equipment, but those growth of import stopped in 2020 due to decrease in import of Ukraine conducted with starting of world pandemia in 2020. The increase of the emissions in 2021 are associated with growth in HFCs imports in some categories as well as with HFCs that stayed in operated equipment.

In 2021, there were no PFCs imports to Ukraine since there was no production need for it. Thus, PFCs emissions in 2021 are zero.

There are no emissions of NF_3 due to absence of activities related to production of photo-voltaic elements in Ukraine, according to data obtained from the companies that use photovoltaic elements in their production processes.

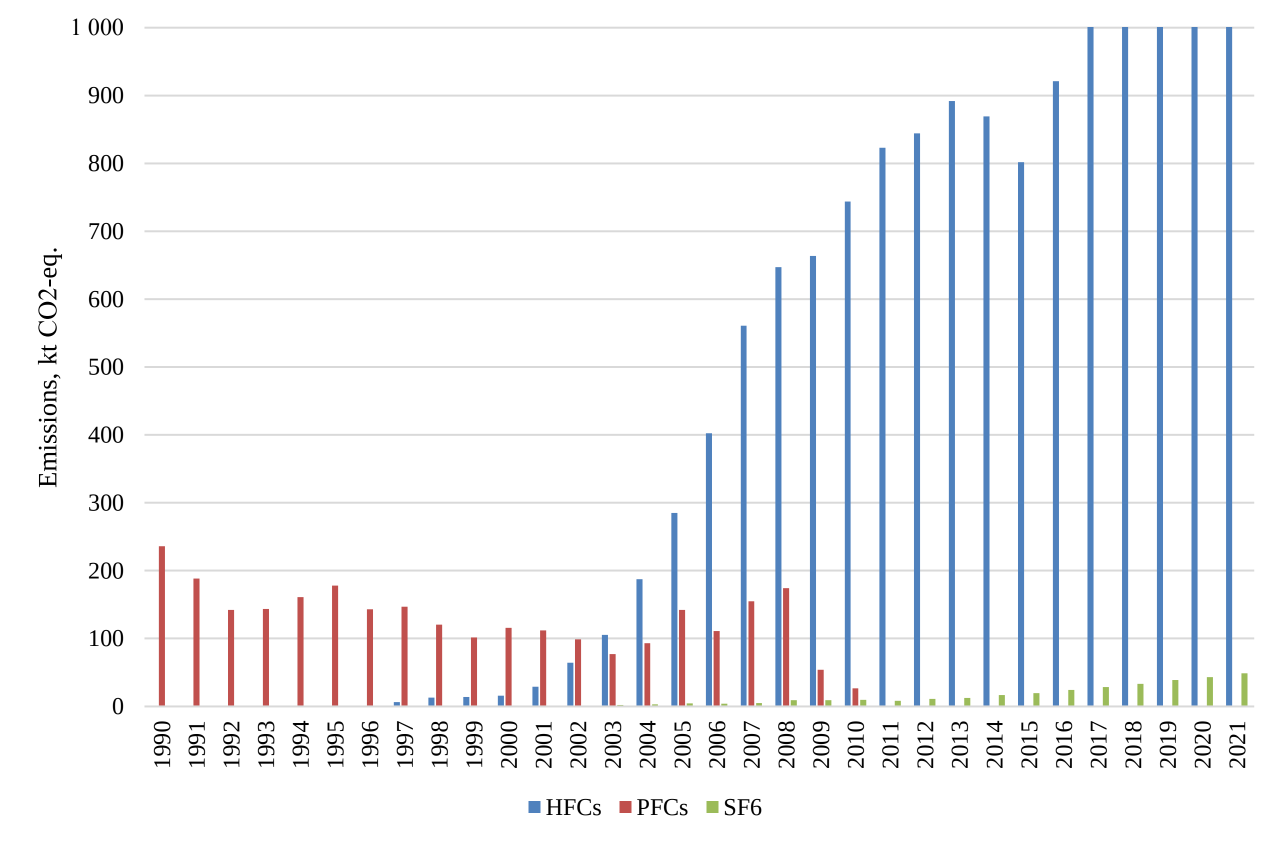

Fig. 2.5. Emissions of PFCs, HFCs and SF_6 in Ukraine, kt CO_2-eq.

2.1.5 Trends in emissions of precursor gases and SO_2

Fig. 2.6 presents trends for all precursor emissions (nitrogen oxides, carbon monoxide, non-methane volatile organic compounds) and sulfur dioxide in 1990-2021. In 1990, more than 90% of NOx, CO and SO_2 emissions occurred the Energy sector, almost all the rest - in the sector IPPU, since in the LULUCF sector emissions of these gases occur in very small amounts from wildfires, and in the Agriculture sector they do not occur at all. The leading pace of SO_2 emission reduction compared with GHG emissions in the period of 1990-2021 are mainly related with substitution of fuel oil (with a significant content of sulfur) by natural gas (sulfur content of which is small) in the fuel balance of Ukraine.

CO emission trends are explained by two key factors. The leading trend of CO emission reduction compared with GHG emissions associated primarily with coal substitution by natural gas in private households. At the same time, the influence of this factor is recently offset by an increase in the volume of fuel consumption by road transport, which is the main source of CO emissions in the Energy sector.

NMVOC emissions are observed in the sectors Energy, IPPU and Agriculture, as well as in the LULUCF sector in small amounts during biomass burning.

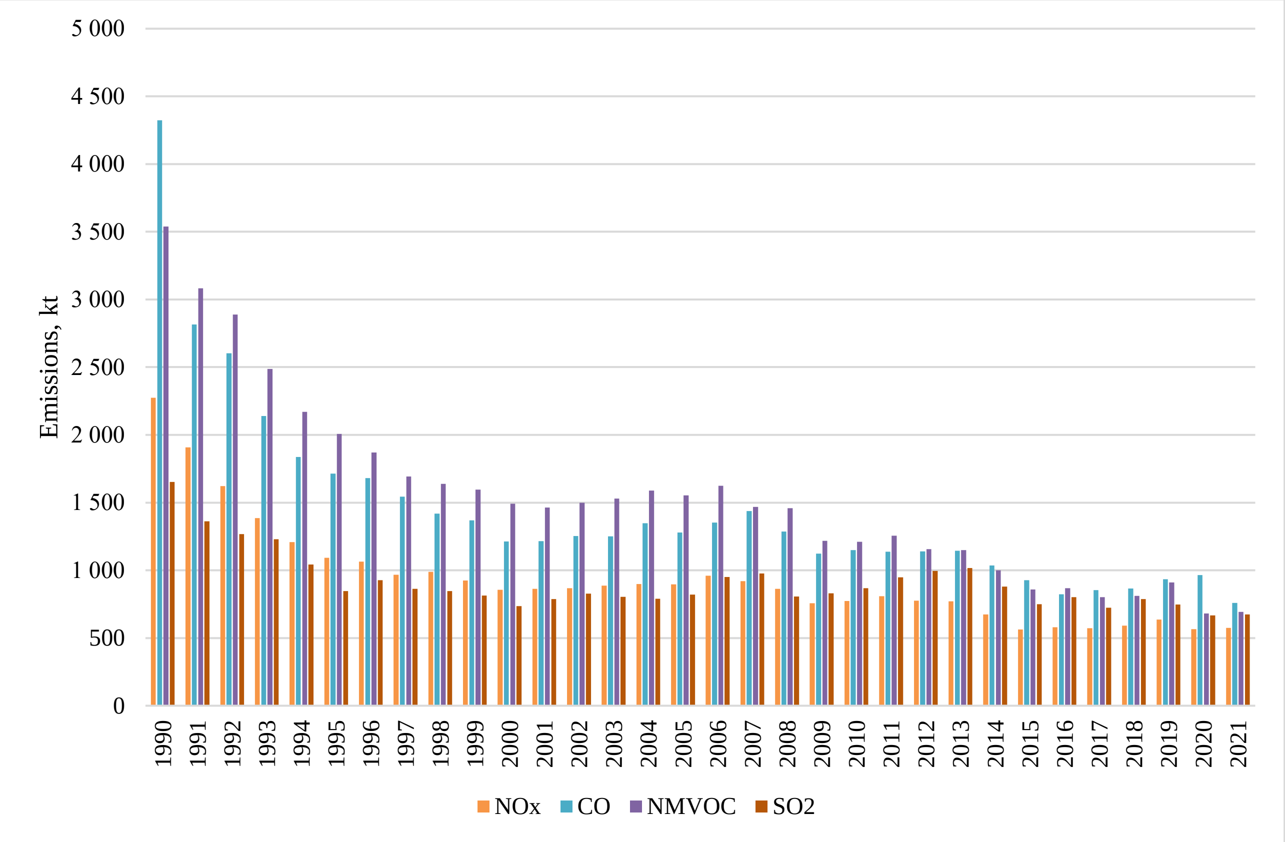

Fig. 2.6. Precursor and SO_2 emissions in Ukraine, kt

2.2 Emission trends by sector

Figure 2.7 and Table 2.2 present GHG emissions and removals in Ukraine by sector for the time series from 1990 to 2021.

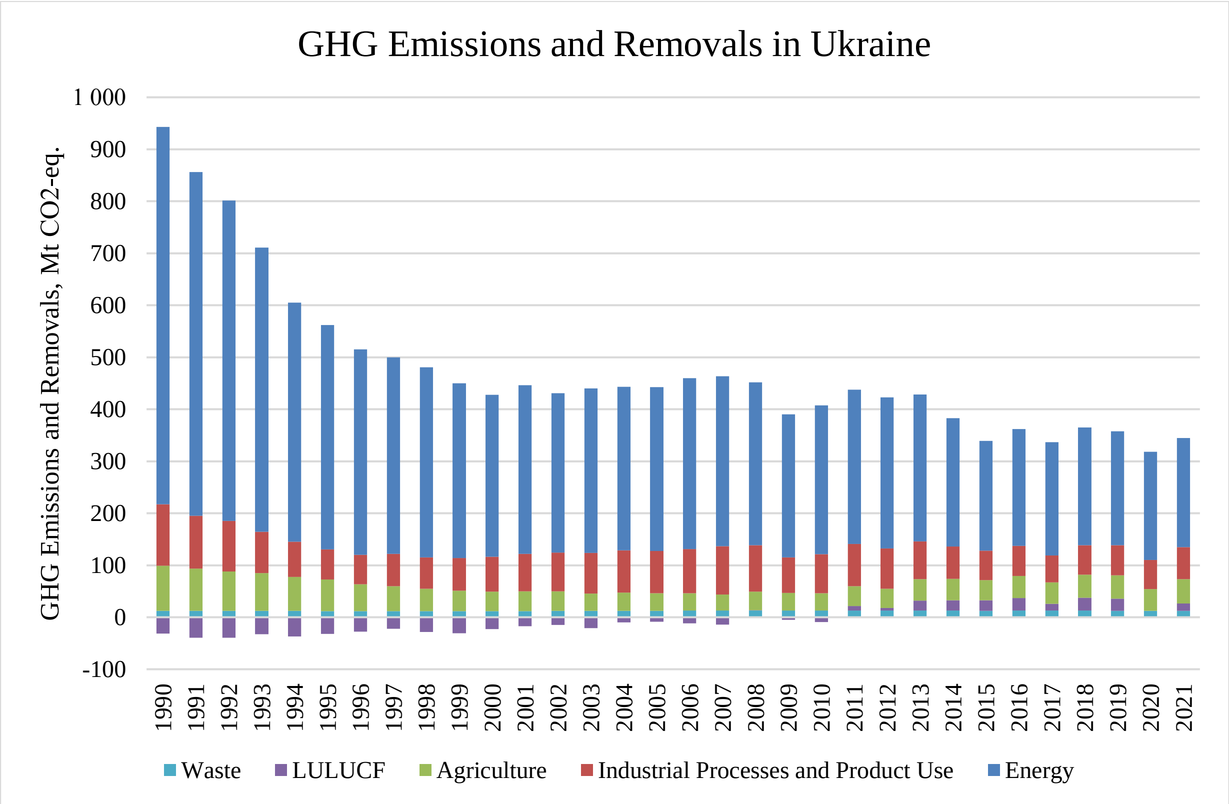

Fig. 2.7. GHG emissions and removals by sector in Ukraine, Mt CO_2-eq.

Table 2.2. Greenhouse gas emissions in Ukraine by sector for the period of 1990-2020 (Mt CO_2-eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Energy	725.3	661.6	615.8	547.0	460.0	431.4	395.4	377.7	366.0	335.8	311.3	324.2	306.6
Industrial Processes and Product Use	118.2	101.3	97.3	79.2	67.2	58.2	56.5	62.1	60.1	62.9	67.5	71.9	74.7
Agriculture	86.8	81.1	75.8	72.6	65.8	60.6	51.6	48.0	43.1	39.4	37.3	38.0	37.8
LULUCF (removals)	-31.4	-39.6	-39.3	-32.8	-37.0	-32.1	-27.7	-22.5	-28.1	-31.0	-22.9	-17.4	-14.8
Waste	12.4	12.4	12.4	12.3	12.0	12.0	11.9	11.8	11.8	11.7	11.8	11.9	12.0
Total (without LULUCF)	942.8	856.4	801.3	711.1	604.9	562.1	515.4	499.6	480.9	449.8	427.9	446.0	431.0
Total (with LULUCF)	911.4	816.8	762.0	678.3	567.9	530.0	487.7	477.2	452.8	418.8	405.0	428.6	416.2
Total (without LULUCF, with indirect)	942.8	856.4	801.3	711.1	604.9	562.1	515.4	499.6	480.9	449.8	427.9	446.0	431.0
Total (with LULUCF, with indirect)	911.4	816.8	762.0	678.3	567.9	530.0	487.7	477.2	452.8	418.8	405.0	428.6	416.2

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy	316.4	314.6	315.1	328.9	327.0	313.3	275.4	286.4	296.5	290.3	282.2	246.7	210.8
Industrial Processes and Product Use	78.3	81.5	81.0	85.3	92.5	89.2	68.6	74.7	81.2	77.7	72.6	62.0	56.4
Agriculture	33.5	34.8	33.9	33.3	31.1	36.0	33.9	33.5	38.4	37.2	41.6	41.4	39.4
LULUCF (removals)	-21.3	-9.6	-8.9	-12.0	-14.1	0.8	-4.7	-9.0	8.6	5.0	19.0	20.1	19.7
Waste	12.1	12.3	12.4	12.6	12.8	12.7	12.6	12.7	12.8	12.6	12.9	12.6	12.6
Total (without LULUCF)	440.3	443.1	442.4	460.0	463.4	451.2	390.5	407.4	428.8	417.8	409.3	362.8	319.2
Total (with LULUCF)	419.1	433.6	433.5	448.0	449.4	452.0	385.8	398.4	437.4	422.9	428.2	382.9	338.9
Total (without LULUCF, with indirect)	440.3	443.1	442.4	460.0	463.4	451.2	390.5	407.4	428.8	417.8	409.3	362.8	319.2
Total (with LULUCF, with indirect)	419.1	433.6	433.5	448.0	449.4	452.0	385.8	398.4	437.4	422.9	428.2	382.9	338.9

	2016	2017	2018	2019	2020	2021
Energy	224.8	217.8	226.3	219.2	208.0	209.7
Industrial Processes and Product Use	58.1	51.9	56.5	57.6	56.0	61.5
Agriculture	42.0	41.0	44.4	44.8	41.7	47.0
LULUCF (removals)	24.4	13.4	24.9	23.3	-0.4	14.2
Waste	12.7	12.7	12.6	12.6	12.4	12.2
Total (without LULUCF)	337.6	323.3	339.8	334.1	318.0	330.4
Total (with LULUCF)	362.0	336.7	364.7	357.5	317.6	344.6
Total (without LULUCF, with indirect)	337.6	323.3	339.8	334.1	318.0	330.4
Total (with LULUCF, with indirect)	362.0	336.7	364.7	357.5	317.6	344.6

The largest contribution to GHG emissions has the Energy sector. Its share in the total emissions for the period of 1990-2021 fluctuated within the range of 60.9-81.4 % with the LULUCF sector, and of 63.5-77.3 % without the LULUCF sector. Decline of emissions in the sector in 2021 compared to 1990 is 71.1 % - from 725.32 to 209.74 Mt CO_2-eq. Compared to 2020 the GHG emissions has increased by 0.8 %.

The largest source of GHG emissions in the Energy sector is thermal power plants (TPPs), which accounted for 37.2-45.2 % of total GHG emissions in the sector. Particularly, along with the tendency of emission reduction in industrial categories, the share of emissions from coal burning at TPPs increased annually. GHG emissions from transport activity (category 1.A.3) amounted from 10.3 % to 17.2 % from Energy sector during the whole time series. The share of GHG emissions in the category 1.A.4 "Other Sectors" in 1990-2020 was 9.1-15.4 %. Reduction of emissions in the category in the recent years is related to reduction of fuel consumption in the commercial as well as residential sectors. It should be noted that in the category 1.A.5 "Other", which corresponds to emissions from use of fuels for military purposes, in the period of 1990-2013 emissions were insignificant and amounted to around 0.01 %. In 2014-2021, the share of emissions from this category was 0.2% of the total emissions in the Energy sector.

Emissions in category 1.B Fugitive emissions were 17.6-28.7 % of total sector's emissions, and in recent years, the share of emissions in the category has been reducing.

The share of emissions in IPPU sector in the period of 1990 - 2021 ranged from 11.0 % to 20.6 % of the total national GHG emissions, including LULUCF (or 10.3 – 20.0 % excluding LULUCF). Total GHG emissions in the sector decreased from 118.20 Mt CO_2-eq. in 1990 to 61.49 Mt CO_2-eq. in 2021 i.e., by 48.0 %.

The largest source of carbon dioxide emissions in this sector is iron, steel, ammonia, cement and ferroalloys production. During the period of 1990-2004, there was steel production and export growth with a simultaneous decrease of volumes of open-hearth steel production. The growth of steel production led to the growth of emissions associated with the technological process, and decrease in open-hearth steel production - to reduction of emissions related to energy consumption. The main factor that caused the increase in CO_2 emissions in 2005-2007 was the increase in production volumes. The period of 2008-2009 is characterized by a sharp decline in production volumes due to the global economic crisis. As a result of the crisis, Ukrainian producers reduced production volumes and started to close down open-hearth furnaces, which led to further decrease of emissions associated with energy consumption, because the liquid oxygen gasification technology gained popularity. At the same time, reducing iron production led to transfer of blast furnaces into the idle mode that caused to the increase of significance of the technological process in the total emissions in 2009-2021. The increase in total emissions in 2021 compared to 2020 is associated with a growth in industrial production by Ukrainian enterprises, as well as a increase in imports of industrial products.

The share of Agriculture sector in the total volume of emissions during 1990-2021 varied in the range from 6.9 % to 13.6 % (or 6.7 – 14.2 % excluding LULUCF). The emissions fluctuation in the sector is related to a change in the number of livestock animals and their herd structure; redistribution of manure shares by MMS; varying amounts of fertilizer and liming materials applied; areas under certain crops and their productivity.

In the LULUCF sector, in 2021 CO_2 emissions exceeded removals. The value of removals reaches 6.9 % to the total emissions in the country in 1999, then gradually decreased to emissions in 2021.

In 2021 net GHG emissions are 14.23 Mt CO_2-eq., in the contrast with the removals in 1990 (31.41 Mt CO_2-eq.), and very contrast compared with removals in 2020 (0.41 Mt CO_2-eq.). Such dynamic is related to first of all GHG emissions dynamic from mineral soils in Cropland category. In 2021 the emissions of 48.26 Mt CO_2-eq. took place on contrast with 27.43 Mt CO_2-eq. of emissions in 2020. Emissions in 2021 are 52.82 Mt CO_2-eq. higher, than the level of 1990, when 4.6 Mt CO_2-eq. GHG removals occurred. Such variability in emissions relates to instability of volumes of agricultural crop production, change in structure of crops and level of fertilizers applied, especially organic, between the years.

Moreover, forest fires, drainage of organic soils in forests and in Cropland and to a lesser extent in Grassland land-use categories have its influence. It should also be noted that in 1990 a large share of GHG emissions in this category had emissions from non-energy peat extraction, resulting in 12.03 Mt CO_2-eq., but by 2020 the decline in peat production and peat areas reduced the emissions down to the level of 0.25 Mt CO_2-eq.

The share of the Waste sector is small, ranged from 1.4 % to 3.9 % of the total national emissions. Fluctuations in emissions are caused by the following factors: from 1990 to 1999, gradual emissions decrease was caused by sharp drop in industrial production; from 1999 to 2007, significant emissions increase was caused by an increase in the volumes of municipal solid waste landfilling, as well as an increase in the volume of industrial wastewater; since 2013, emissions started to decrease constantly mainly due to the reduction of water consumption for industrial and household needs and an increase of methane utilization at MSW landfills.

3 ENERGY (CRF SECTOR 1)

3.1 Sector Overview

The "Energy" sector includes emissions from combustion of carbonaceous fuels (category 1.A "Fuel Combustion Activities"), as well as greenhouse gases produced as a result of leaks in extraction, processing, storage, transportation, and consumption of fuels (category 1.B "Fugitive Emissions from Fuels").

In the reporting year, GHG emissions in the "Energy" sector amounted to 209.74 Mt of CO_2-eq. or approximately 66.0% of all GHG emissions in Ukraine (excluding sinks in the "LULUCF" sector), and decreased by 71.08% vs the baseline 1990. Compared with 2020 emissions increased by 0.8%.

Fig. 3.1 shows changes in GHG emissions in the "Energy" sector. In 1990, the proportion of carbon dioxide, methane, and nitrous oxide in the total emissions in the sector accounted for 81.7%, 17.6% and 0.7%, while in 2021 – 76.16%, 23.11% and 0.73%, respectively.

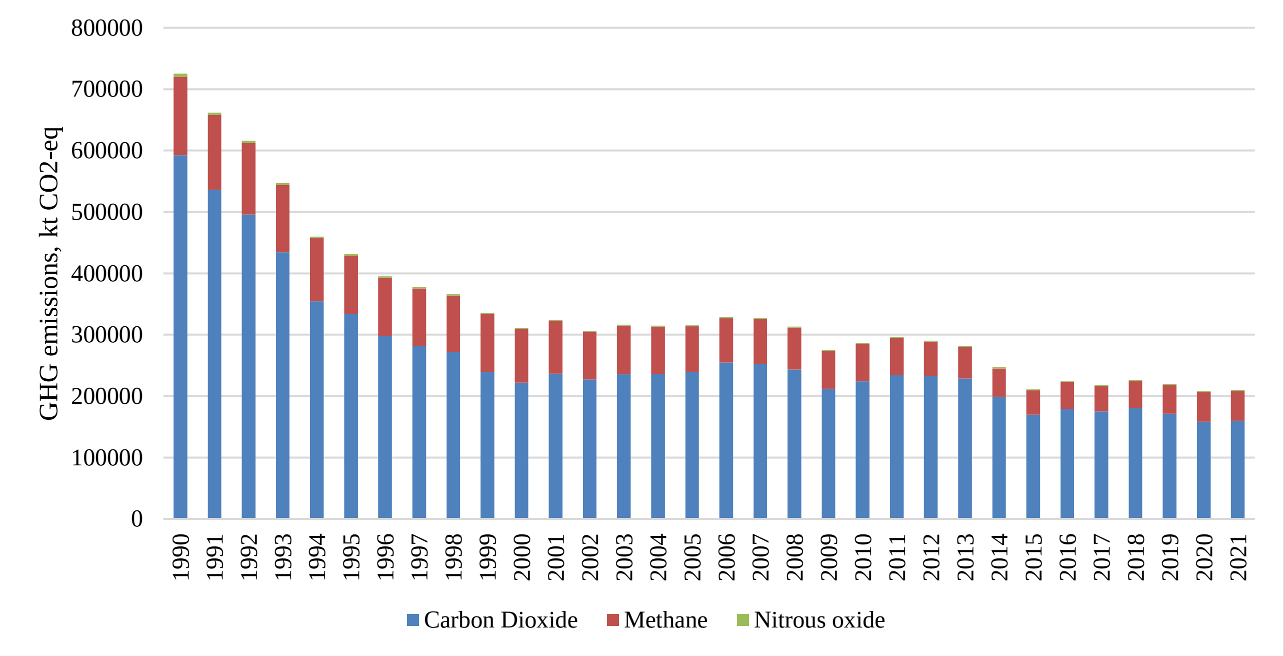

Fig. 3.1. GHG emissions in the "Energy" sector, 1990-2021

In 2021, approximately 75.99% of emissions in the sector accounted for emissions in category 1.A "Fuel Combustion Activities", and emissions in category 1.B "Fugitive Emissions from Fuels" – 24.01% (Table 3.1).

Table 3.1. GHG emissions in the "Energy" sector, Mt of CO_2-eq.

Category	1990	1995	2000	2005	2010	2012	2016	2017	2018	2019	2020	2021
1 Energy total, including:	725.32	431.38	311.34	315.11	286.38	290.29	224.76	217.75	226.30	219.17	207.99	209.74
1.A Fuel Combustion Activities	597.85	335.35	222.13	239.41	223.70	232.60	178.81	174.75	180.59	171.24	157.57	159.39
1.B Fugitive Emissions from Fuels	127.47	96.02	89.21	75.70	62.68	57.69	45.96	43.00	45.71	47.93	50.42	50.36

The dynamics of GHG emissions in the "Energy" sector in the period of 1990-2021 were diverse on certain parts of the time series.

In 1990-1993 GHG emissions were gradually and rapidly reducing, which is due to the inertia of the collapse of the Ukrainian SSR economy and of the Soviet Union as a whole.

In 1994, there was the greatest reduction of GHG emissions - by 15.9% compared to the previous year 1993, followed by a slowdown of annual reductions till 2000, inclusive. This period is characterized by a sharp reduction in production capacity and idle periods for enterprises, as well as gradual "aging" of the industrial capital and the national infrastructure.

In the period of 2000-2007, there was a slight increase of GHG emissions along with a faster rate of capacity buildup in the production sector. Over the reporting period, GHG emissions increased by 7.1%, due to a number of macro-economic, political, administrative, and social factors. Among the key reasons, the following should be noted: opening of new international markets with tough competition, political and economic measures to improve energy efficiency in the energy sector in Ukraine, international economic and personnel cooperation on energy efficiency and energy saving, energy price trends, transition to private property management.

Since 2007, the key influence on the trend of annual GHG emissions was exerted by the global economic crisis of 2008, which affected the non-production sector mostly, as well as the situation in the global markets of energy-intensive products (e.g. metallurgy), and the policy of natural gas substitution with coal by introducing the pulverized coal injection technology.

Recent years are characterized by general decline in industrial production aggravated by COVID epidemic, and corresponding reduce of production and GHG emissions in the energy sector.

3.2 Fuel Combustion Activities (CRF category 1.A)

Category 1.A "Fuel Combustion Activities" includes emissions from combustion of carbonaceous fuels.

The estimation of CO_2 emissions in accordance with [1] was performed by two methods – sectoral and baseline. Estimation of other GHG emissions was held with the sectoral approach.

In 2021, emissions from fuel combustion amounted to 159.4 Mt of CO_2-eq. and decreased as compared to 1990 by 73.34%, compared with 2020 emissions increased by 1.15%.

More detailed information is presented in Fig. 3.2.

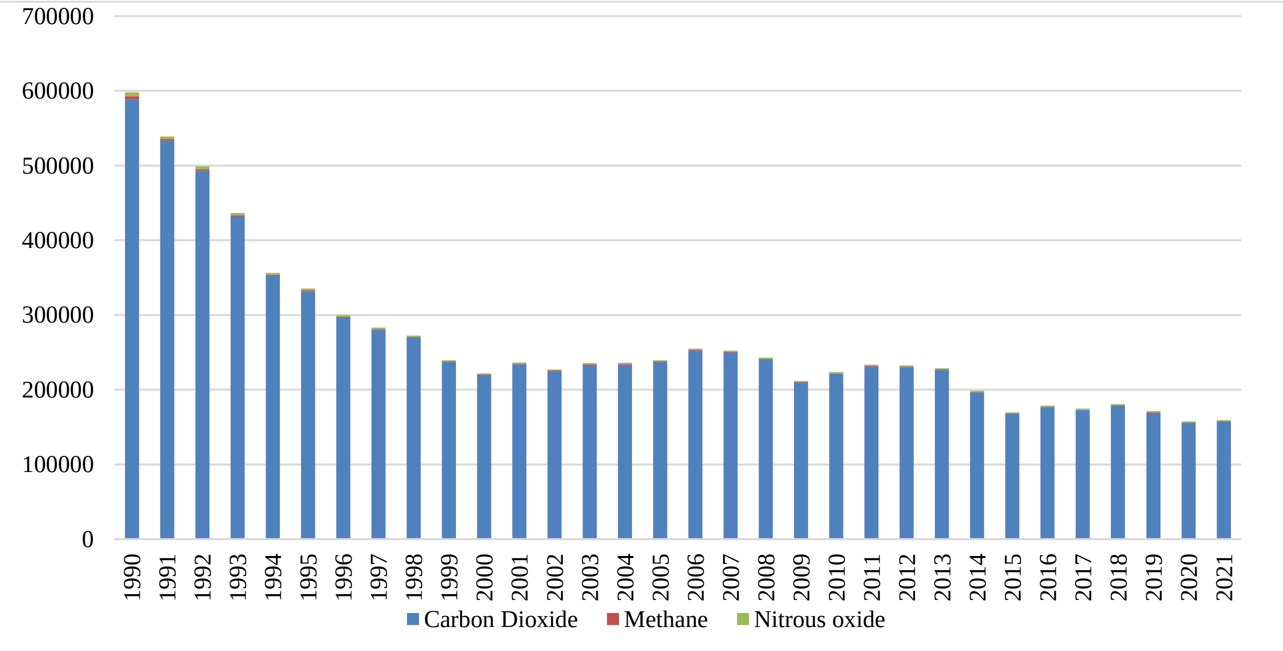

Fig. 3.2. GHG emissions in category 1.A "Fuel Combustion Activities" (sectoral approach, kt CO_2-eq.), 1990-2021

The key source of greenhouse gases is category 1.A.1 "Energy Industries", which in 1990 accounted for 45.6% of all emissions in the category and in 2021 – 53.48%; the share of 1.A.2 "Manufacturing Industries and Construction" was 18.6% in 1990 and 13.18% in 2021; 1.A.3 "Transport"

– 18.7% and 21.12%, respectively; 1.A.4 "Other sectors" – 17.1% and 11.97%, respectively, the contribution of 1.A.5 "Other" was negligible until 2013, in 2021 it amounted to 0.24% (according to Table 3.2).

Table 3.2. GHG emissions in category 1.A "Fuel Combustion Activities", Mt of CO_2-eq.

Category	1990	1995	2000	2005	2010	2012	2016	2017	2018	2019	2020	2021
1.A Fuel Combustion Activities total, including:	597.85	335.35	222.13	239.41	223.70	232.60	178.81	174.75	180.59	171.24	157.57	159.40
1.A.1 Energy Industries	272.68	194.73	115.78	120.79	121.41	131.21	98.86	90.45	98.75	92.22	86.40	85.24
1.A.2 Manufacturing Industries and Construction	111.26	24.99	31.23	36.79	22.60	22.92	18.40	18.05	18.42	18.61	19.82	21.01
1.A.3 Transport	111.79	49.22	34.55	39.19	40.20	39.36	32.89	34.94	34.96	37.73	31.81	33.67
1.A.4 Other sectors	102.01	66.35	40.50	42.55	39.46	38.99	28.12	30.78	27.99	22.32	19.08	19.08
1.A.5 Other	0.11	0.06	0.06	0.08	0.03	0.12	0.53	0.53	0.48	0.36	0.45	0.38

Changes in the structure of emissions from fuel combustion in the period of 1990-2021 by IPCC categories are presented in the diagram (Fig. 3.3).

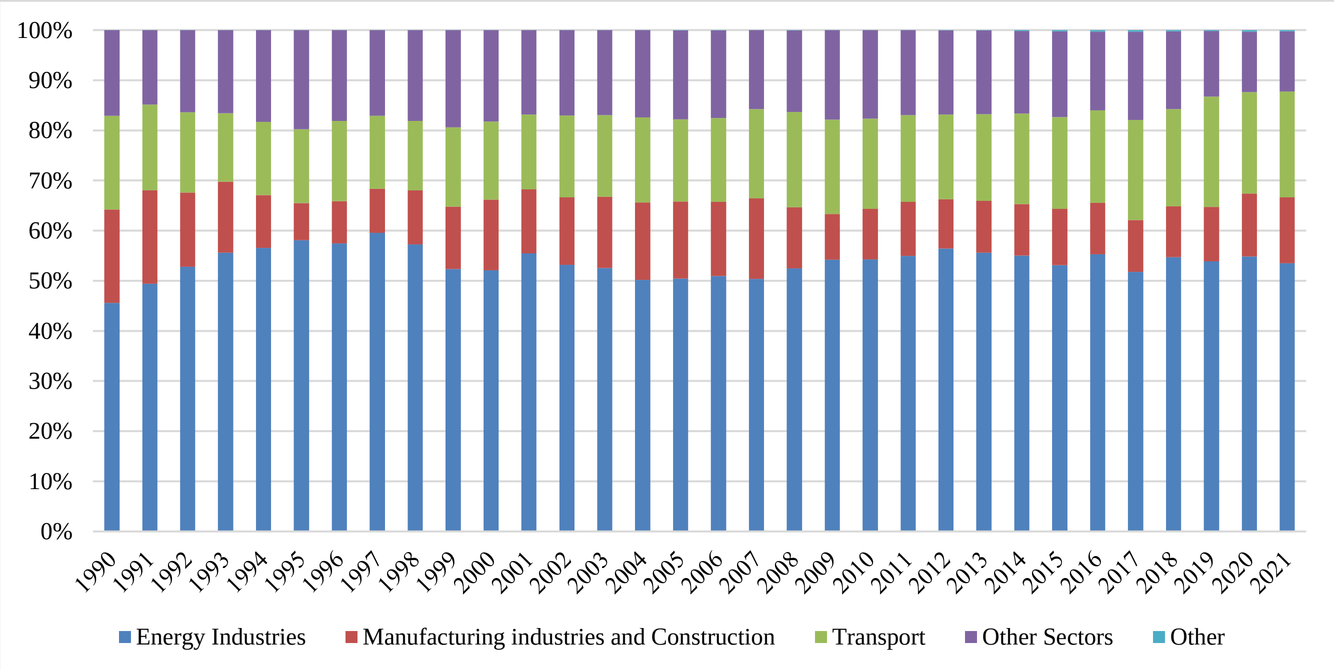

Fig. 3.3. Changes in the structure of emissions from fuel combustion by IPCC categories

3.2.1 Reference CO_2 emission calculation approach. Comparison of sectoral and reference approaches

As a cross-check of the total amount of CO_2 emissions from fuel combustion, comparison of the results of the reference and sectoral approach application was performed (see Table 3.3).

The emission estimation for the reference approach was held in accordance with equation 6.1 [1].

The emission factors for estimation of GHG emissions under the reference approach were NCV and the carbon content same as the values applied in the sectoral approach (see Annex A2.5). Exceptions are emission factors for coals, which were determined as the average for Ukraine as a weighted average value for the coal used in TPPs and for other needs in the country as a whole.

Carbon withdrawal was held in several stages. In the first stage under the reference approach carbon related to non-energy use of fuels according to form 4-MTP was withdrawn. Besides, when estimating non-energy consumption of fuels, consumption of hard coal processing products for the purpose of production of carbon black in the country was taken into account.

Due to the fact that emissions from use of coke in ferrous metal production and of natural gas in ammonia production are estimated in accordance with [1] in categories 2.C.1 and 2.B.1 respectively, at the second stage for an adequate comparison of the approaches the carbon contained in coke and natural gas used for the processes above was defined as withdrawn (stored) carbon.

For 2021 the information on production, imports and exports is available from appropriate statistical forms but the information on stock change and carbon excluded is not available because of absence of the form 4-MTP and IEA questionnaires for 2021. These missing data is assumed to be equal to the date from 2020 taking into account similar conditions in terms of production, consuming, COVID impact.

Table 3.3. Comparison of CO_2 emissions from fuel combustion determined using the reference and sectoral approaches

Year	CO_2 emissions determined using the reference approach, Mt	CO_2 emissions determined using the sectoral approach, Mt	Discrepancy between sectoral and reference approaches, %
1990	608.89	588.77	3.42
1991	607.27	533.14	13.91
1992	525.63	493.09	6.60
1993	418.70	431.68	-3.01
1994	349.85	352.27	-0.69
1995	342.88	331.26	3.51
1996	283.00	296.01	-4.39
1997	267.35	279.77	-4.44
1998	258.89	269.52	-3.94
1999	239.97	236.75	1.36
2000	229.81	219.70	4.60
2001	232.06	234.10	-0.87
2002	243.29	224.75	8.25
2003	232.21	233.15	-0.40
2004	242.71	233.57	3.91
2005	249.79	237.07	5.36
2006	259.67	252.26	2.94
2007	260.54	249.92	4.25
2008	245.66	240.51	2.14
2009	209.75	209.51	0.12
2010	219.17	221.30	-0.96
2011	232.55	231.00	0.67
2012	225.91	230.10	-1.82
2013	217.05	226.23	-4.06
2014	196.82	196.49	0.17
2015	176.60	167.61	5.37
2016	174.44	176.67	-1.26
2017	166.17	172.61	-3.73
2018	175.56	178.37	-1.58
2019	166.51	168.94	-1.44
2020	155.07	156.44	-0.44
2021	150.20	157.48	-4,62

3.2.2 International Bunker Fuels (CRF category 1.D.1)

3.2.2.1 International Aviation (CRF category 1.D.1.a)

The approach applied to distribution of GHG emissions between domestic and international aviation is consistent with the approach described in [1]. Emissions from international aviation include emissions from aircraft operations where the departure or destination airports are located outside Ukraine. For more details on the technique of estimating GHG emissions from air transport, as well as the input data, see Annex A2.7.

GHG emissions from international aviation in 2021 amounted to 1263,14 kt of CO_2-eq., which is 45.0% higher than the same indicator in 2020 and 1,95 times lower than in 1990. For trends on GHG emissions from domestic and international aviation see Fig. 3.8.

3.2.2.2 International Waterway Navigation (CRF category 1.D.1.b)

National statistics do not include data on international bunker waterway transportations. In this connection, the indirect estimation method was used, which is based on use of data on total consumption of fuels by water transport (form 4-MTP) and the sea transport cargo turnover (coastal/international transportation) plus the river one (domestic/foreign traffic) [16-29].

The distribution of fuels for international transportation was performed based on the formula:

$$FC_{1.d.1.b} = FC_{H50} \cdot k_{1.d.1.b} \qquad (3.1)$$

Where:

$FC_{1.d.1.b}$ is consumption of fuels by international waterway transport (gasoil, fuel oil), tons;

FC_{H50} - consumption of fuels by TEA H50 "Water Transport" for transportation needs (gasoil, fuel oil), tons;

$K_{1.d.1.b}$ - the factor of fuel distribution into international/coastal transportation, in relative terms, which is defined by the following expression:

$$k_{1.d.1.b} = \frac{PR_{int}+PS_{int}}{PR+PS} \qquad (3.2)$$

Where:

PR_{int} is the volume of cargo transportation by international river transport, thd tons;

PS_{int} is the volume of cargo transportation by international sea transport, thd tons;

PR - total volume of cargo transportation by river transport, thd tons;

PS - total volume of cargo transportation by sea transport, thd tons.

The volumes of cargo transportation were taken from statistical yearbooks [16-29].

The trends in cargo for national and international navigation may be observed in ANNEX 2 fig. A.2.1, fig. A.2.2.

The method used for estimating the emissions corresponds to Tier 2 for CO_2 emissions from diesel combustion and Tier 1 – for fuel oil and non-CO_2 gases in accordance with [1].

Because of absence of necessary statistical information for 2021 GHG emissions from international water transport in 2021 are assumed to be equal to emissions in 2020.

GHG emissions from international water transport in 2021 amounted to 43,48 kt of CO_2-eq., which is equal to that in 2020 and 36.8 times lower than in 1990. GHG emissions from domestic and international navigation for 1990-2021 are presented in the Fig.3.10.

3.2.2.3 Category-specific recalculations

No recalculations were performed in the category

3.2.3 Use of fuels as a raw material and non-energy use of fuels

Emissions in category 1.A "Fuel Combustion Activities" include emissions from fuel combustion for heat and electricity production in industrial processes, transportation, etc. However, fuel is also used for non-energy needs (for example, as solvents, lubricants, etc.; as feedstock for ammonia, rubber, plastic production, etc.; as a reducing agent – coke in the blast furnaces). Emissions from non-energy fuel use are presented in the sector "IPPU" in the following sub-categories:

2.B.1 "Ammonia Production" – natural gas as a raw material in production of ammonia;
2.C.1 "Iron and Steel Production" – non-energy use of coke in production of pig iron in the blast furnace process;
2.C.2 "Ferroalloys Production" – coke in production of ferroalloys;
2.B.8 "Petrochemical and Carbon Black Production" – coal raw material for carbon black production;
2.D.1 "Lubricants Use" – non-energy use of oils;
2.D.2 "Paraffin Wax Use" – non-energy use of paraffin in manufacture of industrial products.

To improve transparency of accounting for emissions from coke use, the balance of coking coal, coke, and coke gas was built, which is presented in Annex A4.4.

The amount of fuel that was used for non-energy needs was determined on the basis of statistical reporting form 4-MTP, where enterprises enter information on fuel quantities used as raw materials for chemical, petrochemical, and other non-fuel production. The exception is natural gas and coke, where the volumes of their use as raw materials were determined according to data of companies producing ammonia, cast iron, steel and carbon black, respectively.

Thus, fuel used for non-energy purposes were not considered in calculation of GHG emissions in category 1.A "Fuel Combustion Activities".

3.2.4 CO_2 sequestration

Ukraine does not conduct sequestration of CO_2 released during combustion of carbon-containing fuels for long-term storage purposes, for example, in geological formations. For this reason, no estimation of the volume of sequestered CO_2 in the "Energy" sector was performed.

3.2.5 CO_2 emissions from biomass

In accordance with [1], CO_2 emissions from combustion of biomass for energy purposes were not included into the total emissions in the "Energy" sector but are presented separately, as reference data. Emissions of CH_4 and N_2O from biomass for energy purposes are accounted for in category 1.A "Energy Industries".

In the emission calculations, biomass includes charcoal, firewood, briquettes and pellets from wood, sawdust briquettes, and biodiesel from oils, sugar and starch crops, and other types of primary fuels (sawdust, bark, corn cobs, etc.).

The method of estimating emissions from biomass, activity data and emission factors are presented in Annex A2.

3.2.6 National features

National characteristics of energy statistics of Ukraine, as well as changes in its structure during the period of 1990-2021, are described in Annexes A2.1-A2.2 and form the basis for processing of input data within the current GHG inventory.

3.2.7 Energy Industries (CRF category 1.A.1)

3.2.7.1 Category Description

In 2021, emissions in category 1.A.1 "Energy Industries" amounted to 85.24 Mt of CO_2-eq., or about 53.48% of the total emissions in category 1.A "Fuel Combustion Activities", and decreased by 68.74% compared with the baseline 1990 (see Table 3.4); they decreased by 1.35% compared to 2020.

Table 3.4. GHG emissions in the category 1.A.1 "Energy Industries", Mt of CO_2-eq.

Emission category	1990	1995	2000	2005	2010	2012	2016	2017	2018	2019	2020	2021
1.A.1 Energy Industries, total	272.68	194.73	115.78	120.79	121.41	131.21	98.86	90.45	98.75	92.22	86.40	85.24
1.A.1.a Electricity and Heat Production	255.52	187.77	108.07	111.58	111.75	123.07	94.50	86.83	93.57	87.83	82.10	80.94
1.A.1.b Petroleum Refining	6.36	1.88	1.40	1.23	0.87	0.57	0.29	0.34	0.37	0.35	0.39	0.42
1.A.1.c Manufacture of Solid Fuel and Other Energy Industries	10.80	5.08	6.31	7.98	8.79	7.57	4.07	3.28	4.81	4.04	3.92	3.87

3.2.7.1.1 Public Electricity and Heat Production (CRF category 1.A.1.a)

This category includes emissions from stationary fuel combustion in production of electricity and heat by TPPs, CHPs, HPs, waste incinerators.

In view of the fact that in the constantly changing structure of the Ukrainian economy lots of power generation facilities of industrial enterprises have been repeatedly transferred to the balance sheet of other companies, thus without changing the actual technological components they were accounted for in other types of economic activities, so with the view of harmonizing the time series category 1.A.1.a "Electricity and Heat Production" also includes activities of enterprises.

In the category "Electricity and Heat Production", GHG emissions in 2021 amounted to 80.94 Mt of CO_2-eq., having decreased with respect to 2020 by 1.41%, and decreased by 68.32% compared with the baseline 1990.

GHG emissions in category 1.A.1.a by fuels groups are presented in Fig. 3.4

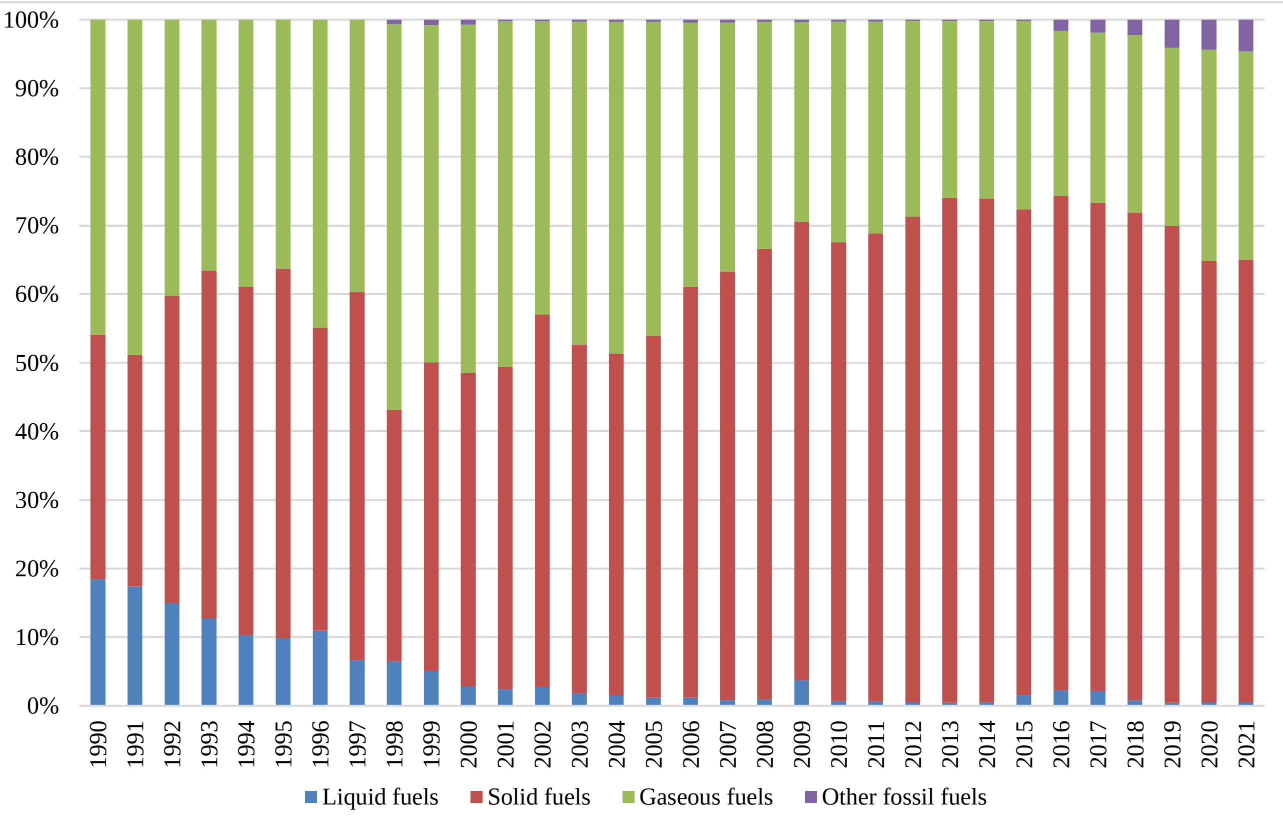

Fig. 3.4. GHG emissions in category 1.A.1.a by fuel groups, % of the category

The structure of GHG emissions in the category 1.A.1.a "Electricity and Heat Production" by energy facilities for 1998-2021 is presented in Fig. 3.5.

For the whole period 1998-2021, the largest share of GHG emissions in the category corresponds to TPPs – from 42.8% to 62.1%, for the rest: CHPs – from 11.9% to 15.8%, HPs – from 45.3% to 22.1%.

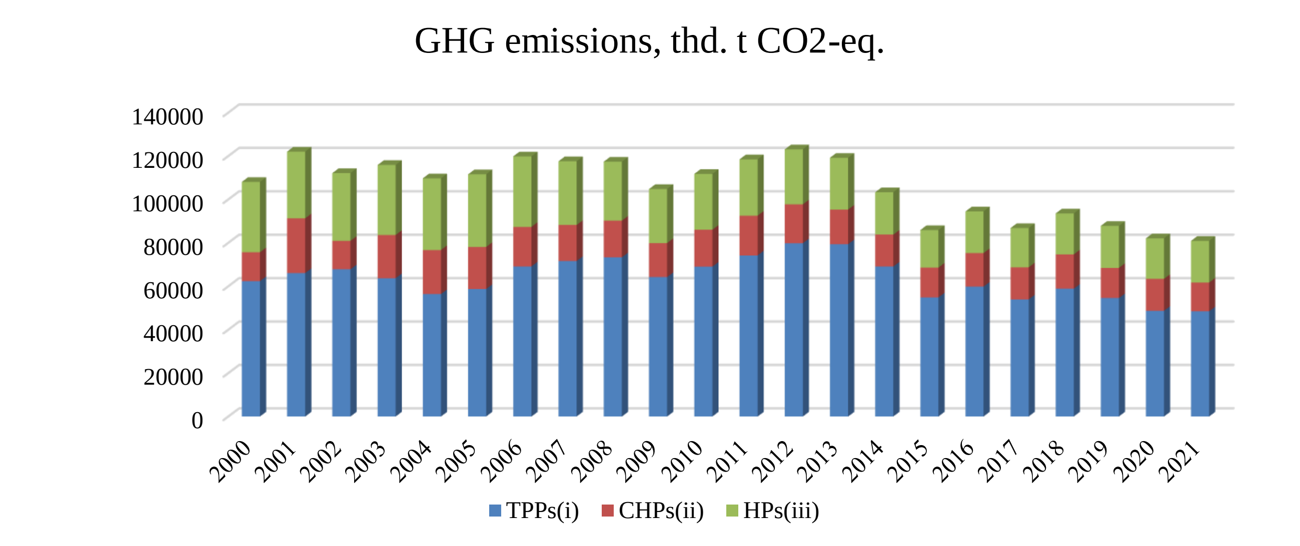

Fig.3.5. The structure of GHG emissions in the category 1.A.1.a "Electricity and Heat Production" by energy facilities, 1998-2021

It should be noted that during recent years the specific fuel consumption (GHG emissions per MWh electricity produced) has the value of 1.0 t CO_2 eq/MWh and even higher because all TPPs blocks are older than 40–50 years and, in order to extend the lifetime, operating steam temperatures are lower, which leads to a higher fuel consumption.

3.2.7.1.2 Petroleum Refining (CRF category 1.A.1.b)

Enterprises in this category include petroleum refineries and gas processing plants. This category accounts for burning fuels directly for technological processes. The key types of fuels in this category are natural gas, refinery feedstock and fuel oils.

In this category, GHG emissions increased by 10% in 2021 compared to 2020 and amounted to 0.42 Mt of CO_2-eq. Compared to 1990, GHG emissions reduced by 14.99 times.

3.2.7.1.3 Manufacture of Solid Fuels and Other Energy Industries (CRF category 1.A.1.c)

This category includes emissions from fuel combustion at the enterprises that are engaged in production of energy materials and other energy industries.

The current inventory in the category takes into account emissions from coal bed methane recovery (with generation of heat and power).

Emissions in this category in 2021 amounted to 3.87 Mt of CO_2-eq, which is 1.27% lower than the same indicator in 2020 and 64.18% lower than the baseline 1990.

3.2.7.2 Methodological Issues

GHG emissions from fossil fuel combustion in all categories were calculated using the methodology described in Annex 2. The key principles for definition of activity data are presented in section A2.2, analysis of the statistical base in Ukraine – in section A2.1, emission factors – in section A2.5, summary data on use of fuels in Ukraine in 2021 – in section A2.9. National circumstances for 2014 - 2021 are provided in Annex A2.10.

Because of absence of some statistical information for 2021 the missing data for GHG emissions estimation in 2021 were calculated on the basis of 2020 data using such drivers as electric energy, heat and refinery production.

3.2.7.2.1 Electricity and Heat Production (CRF category 1.A.1.a)

GHG emissions from coal combustion at the TPPs were estimated based on the methodology, developed by Coal Energy Technology Institute of NASU [11] according to which the country-specific NCV, oxidation factor and carbon content as well as mass combusted were determined for the period 1990-2021 (Annex A2.6.2).

Other fuels consumed in subcategories "Electricity Generation" (i), "Combined Heat and Power Generation" (ii), and "Heat Plants" (iii) were identified based on national statistical forms, see Annex A2.2.

Due to the fact that the national statistics for 1990-1997 does not make it possible to disaggregate data on fuel consumption into the sub-categories "Electricity Generation" (i), "Combined Heat and Power Generation" (ii), and "Heat Plants" (iii), emissions in the category "Electricity and Heat Production" were not disaggregated by the sub-categories above for this period.

Estimation of CO_2 emissions for coal combusted at the TPPs was performed in the manner corresponding to Tier 3 [1]; for natural gas, coal coke, gasoline, diesel and LPG – to Tier 2; for other fuels – to Tier 1.

Calculation of emissions of non-CO_2 gases for all fuels was held under Tier 1 [1].

This category also includes GHG emissions from waste incineration to produce heat energy. In the total CO_2 emissions from combustion of waste of non-biogenic origin at waste incineration plants were implicitly taken into account. CO_2 emissions from combustion of biogenic waste at incineration plants are separately presented as burning of biomass in accordance with [1].

3.2.7.2.2 Petroleum Refining (CRF category 1.A.1.b)

This category includes emissions from combustion of fuels, the energy of which is directly used for oil refining technological processes. The key fuels in the category are: natural gas, refinery feedstock and fuel oils.

The data on energy use of fuel in this sub-category up to 2016 (see A.2.2) are based on the total fuel consumption for oil refining by fuels under form 11-MTP. GHG estimations for the period 2016-2021 were carried out by surrogate method on the basis of IEA data on refinery intake.

Estimation of CO_2 emissions was held under the method corresponding to Tier 1 in accordance with [1].

3.2.7.2.3 Manufacture of Solid Fuels and Other Energy Industries (CRF category 1.A.1.c)

This category includes all GHG emissions from use of solid fuel production and other activities in the energy sector.

Estimation of CO_2 emissions from combustion of natural gas, gasoline, diesel and LPG was held under the method corresponding to Tier 2 in accordance with [1], for other fuels, as well as for non-CO_2 gases – to Tier 1.

GHG emissions from coal bed methane recovery were estimated according to equation 1.4.5. [1]. The input data on coal bed methane recovery up to 2012 are shown in the table 3.19. GHG emissions from coal bed methane for the period 2013-2021 were calculated by surrogate method on the basis coal production data.

3.2.7.3 Uncertainties and Time Series Consistency

Uncertainties of activity data and emission factors are presented in Table 3.5.

Table 3.5. Uncertainties of activity data and emission factors in category 1.A.1 “Energy Industries”

Type of fuel	Uncertainty of activity data, %	Uncertainties of emissions factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	6.71	2	150	500
Solid fuel	7.15	5	150	500
Gaseous fuel	6.99	5	150	500
Other types of fuels	47.05	5	150	500
Biomass	45.34	5	150	500

Quantification of the uncertainty was performed on the basis of the above uncertainty values of activity data and emission factors according to the methodology [1].

Estimated total GHG emission uncertainty in this category is 6.20%.

The most significant impact on the overall uncertainty of GHG emission estimation in this category is produced by CO_2 emission estimation uncertainty in the category “Electricity and Heat Production” – the uncertainty of emission factors and activity data for solid fuel.

3.2.7.4 Category-specific QA/QC Procedures

As part of QA/QC procedures, in addition to the general QA/QC procedures, the following were performed:

– comparison of data on fuel consumption according to forms of statistical reporting 4-MTP and 11-MTP for 2010-2015;

– comparison of data on coal consumption for the period of 2003-2021 obtained from public power stations, with statistics. The average discrepancy for the specified period is about 1%. A more conservative value was used for calculation;

– in collaboration with SSSU’s specialists, analysis of statistical reporting forms containing the source data for GHG emission calculation was conducted;

– balance sheets for various types of fuel were developed (see Annex 4).

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3.2.7.5 Category-specific Recalculations

In this category, no recalculations were made.

3.2.7.6 Category-specific Planned Improvements

In this category, no improvements are planned.

3.2.8 Manufacturing Industries and Construction (CRF category 1.A.2)

3.2.8.1 Category Description and Methodological Issues

This category includes GHG emissions from stationary combustion of fossil fuels used for industrial purposes in industry, construction, and extraction of non-energy materials.

In 2021, emissions in category 1.A.2 “Manufacturing Industries and Construction” amounted to 21.01 Mt of CO_2-eq. or about 13.18% of the total emissions in category 1.A "Fuel Combustion", and decreased by 82.2% compared with 1990 (see Table 3.7). Compared with 2020 emissions increased by 6.02%.

Table 3.7. GHG emissions in category 1.A.2 “Manufacturing Industries and Construction”,Mt of CO_2-eq.

Emission category	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019	2020	2021
1.A.2 Manufacturing Industries and Construction total, including:	111.26	24.99	31.23	36.79	22.60	22.92	20.39	18.40	18.05	18.42	18.61	19.82	21.01
1.A.2.a Iron and Steel	55.35	15.39	25.19	24.59	13.42	13.92	12.45	10.37	9.94	10.19	10.60	11.06	11.38

Emission category	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019	2020	2021
1.A.2.b Non-Ferrous Metals	0.65	0.61	0.47	0.67	0.63	0.36	0.85	0.76	0.80	0.90	0.84	0.84	0.93
1.A.2.c Chemicals	3.52	1.57	0.79	1.11	0.82	0.99	0.46	0.54	0.36	0.56	0.49	0.38	0.41
1.A.2.d Pulp, Paper and Print	0.14	0.20	0.01	0.05	0.04	0.05	0.01	0.05	0.04	0.05	0.04	0.05	0.05
1.A.2.e Food Processing, Beverages, and Tobacco	3.64	2.42	0.90	0.83	0.58	0.63	0.52	0.50	0.51	0.58	0.52	0.53	0.58
1.A.2.f Non-Metal Minerals	16.10	2.61	2.29	5.83	4.27	4.07	3.46	3.66	3.33	3.62	3.98	4.31	4.74
1.A.2.g Other Industries	31.85	2.20	1.56	3.72	2.84	2.90	2.63	2.52	3.07	2.51	2.14	2.65	2.92

Changes in the structure of emissions from fuel combustion in the period of 1990-2021 by category 1.A.2 are presented in the diagram (Fig. 3.6).

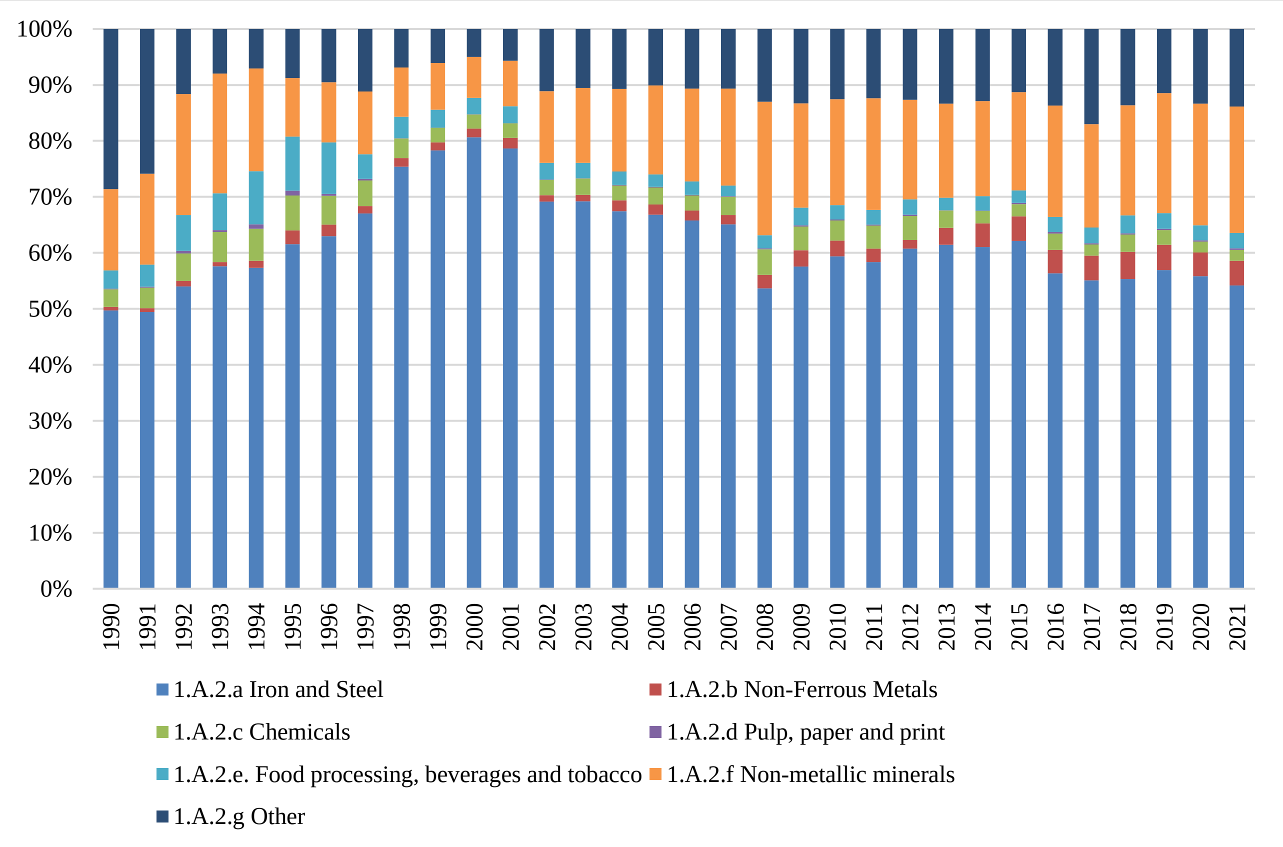


Fig.3.6. Changes in the structure of emissions from fuel combustion in category 1.A.2 "Manufacturing Industries and Construction", %

Emissions that result from use of fossil fuels or their processing products as raw materials or chemical reagents are recorded in CRF sector 2 "IPPU". The same sector accounts for emissions from technological (energy and non-energy components) use of natural gas for the purpose of production of ammonia, as well as coke for recovery of iron ore, since iron, steel and ammonia production processes [5, 6] in Ukraine are characterized by use of fuel resource data directly in the production borders of enterprises of the types and therefore, in accordance, with [1].

Because of absence of some statistical information for 2021 the missing data for GHG emissions estimation in 2021 were calculated on the basis of 2020 data using such drivers as production of pig iron and general industrial production.

3.2.8.1.1 Iron and Steel (CRF category 1.A.2.a)

In accordance to 2006 IPCC Guidelines [1], emissions from energy and non-energy use of coke in the blast furnace process for iron production were accounted in the "IPPU" sector.

In 2021, GHG emissions in this category amounted to 11.38 Mt of CO_2-eq, which is 2.87% higher than the same indicator in 2020 and 79.44% lower than in 1990.

3.2.8.1.2 Non-Ferrous Metals (CRF category 1.A.2.b)

Non-ferrous metallurgy in Ukraine, in contrast to the ferrous one, accounts for a small share of both emissions and fuel resource consumption. However, the sector is characterized by higher energy intensity.

The major share in production of non-ferrous metals belongs to zinc and lead.

Production of primary aluminum in Ukraine stopped in May 2010. However, GHG emission trends in the category of "Non-Ferrous Metals" were not impacted by that, as the key source of electric power at enterprises producing aluminum was power plants.

In 2021, GHG emissions amounted to 0.93Mt of CO_2-eq, increased by 10% compared to 2020 and 41.9% higher than in 1990.

3.2.8.1.3 Chemicals (CRF category 1.A.2.c)

The key products of the chemical industry in Ukraine are ammonia, mineral fertilizers (carbamide, ammonium nitrate, and others), acids (sulfuric, nitric, and others), soda, as well as plastics and rubber products. The chemical industry is one of the largest industrial consumers of natural gas in Ukraine after the thermal power industry and the ferrous industry. Natural gas used for production of ammonia is accounted for in IPPU according to [1].

In 2021, GHG emissions in this category amounted to 0.41 Mt of CO_2-eq., which is 10% higher than the same indicator in 2020 and 8.5 times lower than in 1990.

3.2.8.1.4 Pulp, Paper, and Print (CRF category 1.A.2.d)

This category includes emissions resulting from energy use of fuels by enterprises producing paper and paperboard, products from them, as well as use for publishing and printing for production needs.

Due to the fact that pulp, paper, and printing industries in Ukraine tend to use centralized energy supply systems, waste paper is virtually not used at these plants for energy purposes but consumed as raw materials for reproduction, handed over as waste paper, as well as transferred to other enterprises.

In 2021, GHG emissions in this category amounted to 0.05 Mt of CO_2-eq., which is 10% higher than the same indicator in 2020 and 62.3% lower than in 1990.

3.2.8.1.5 Food Industry, Beverages, and Tobacco (CRF category 1.A.2.e)

In category 1.A.2.e "Food Processing, Beverages, and Tobacco" GHG emissions from use of fuels for production of industrial products were accounted. The key source of emissions in this category are companies engaged in the sugar, baking, and dairy industries, as well as the beverage industry.

In 2021, GHG emissions in this category amounted to 0.58 Mt of CO_2-eq., which is 10.0% higher than the same indicator in 2020 and 6.3 times lower than in 1990.

3.2.8.1.6 Non-Metal Minerals (CRF category 1.A.2.f)

This category includes GHG emissions from use of fuels for production of glass products, materials for construction and other non-metal materials.

In 2021, GHG emissions in this category amounted to 4.74 Mt of CO_2-eq., which is 10.0% higher than the same indicator in 2020 and 3,4 times lower than in 1990.

3.2.8.1.7 Other Industries (CRF category 1.A.2.g)

These industries include emissions from use of fuels for production of industrial products by the Ukrainian enterprises not covered in categories 1.A.2.a - 1.A.2.f namely: construction, machinery, wood products, furniture, electronics, textiles, and so on.

In 2021, GHG emissions in this category amounted to 2.92Mt of CO_2-eq., which is 10.0% higher than the same indicator in 2020 and 10.92 times lower than in 1990.

3.2.8.2 Methodological Issues

GHG emissions from fuel combustion in all the categories were calculated using the methodology described in Annex 2, and are based on statistical data on consumption of fuels presented in the statistical reporting form 4-MTP. National circumstances for 2014-2021 are provided in Annex A2.10.

Because of absence of some statistical information for 2021 the missing data for GHG emissions estimation in 2021 were calculated on the basis of 2020 data using such drivers as production of pig iron and general industrial production.

3.2.8.3 Uncertainties and Time Series Consistency

Uncertainties of activity data and emission factors are present in Table 3.8.

Table 3.8. Uncertainties of activity data and emission factors in category 1.A.2 "Manufacturing Industries and Construction"

Type of fuel	Uncertainty of activity data, %	Uncertainties of emissions factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	12.54	2	150	500
Solid fuel	15.78	5	150	500
Gaseous fuel	14.10	5	150	500
Other types of fuels	30.30	5	150	500
Biomass	30.19	5	150	500

Quantification of the uncertainty was performed on the basis of the above uncertainty values of activity data and emission factors according to the methodology [1].

Estimated total GHG emission uncertainty in this category is 10.6%.

3.2.8.4 Category-specific QA/QC Procedures

In addition to general QA/QC procedures, in this category an analysis of statistical reporting forms containing the original data for the calculation of GHG emissions was held together with specialists from the SSSU.

3.2.8.5 Category-specific Recalculations

In this category, no recalculations were made

3.2.8.6 Category-specific Planned Improvements

No improvements are planned.

3.2.9 Transport (CRF category 1.A.3)

3.2.9.1 Category Description

Category 1.A.3 "Transport" includes emissions from fuel combustion in all modes of transport in Ukraine.

In 2021, emissions in category 1.A.3 "Transport" amounted to 33.67 Mt of CO_2-eq. Compared to 1990, emissions decreased by 69.88%, to the previous 2020 - increased by 5.82%.

The largest contribution into GHG emissions in category 1.A.3 "Transport" in 2021 was made by emissions in categories 1.A.3.b "Road Transport" and 1.A.3.e "Other Types of Transportation" – 74.2% and 23.74%, respectively (see Table 3.10).

Table 3.10. GHG emissions in category 1.A.3 "Transport", Mt of CO_2-eq.

Emission category	**1990**	**1995**	**2000**	**2005**	**2010**	**2012**	**2014**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
1.A.3 Transport total, including:	111.79	49.22	34.55	39.19	40.20	39.36	35.89	32.89	34.94	34.96	37.73	31.81	33.67
1.A.3.a Civil Aviation	0.68	0.11	0.07	0.20	0.17	0.20	0.09	0.13	0.17	0.17	0.18	0.16	0.19
1.A.3.b Road Transport	61.37	20.73	15.78	22.16	28.89	29.10	26.73	23.96	24.68	24.72	26.65	23.37	24.98
1.A.3.c Railways	3.83	1.32	1.39	0.88	0.55	0.38	0.45	0.47	0.56	0.57	0.59	0.42	0.42
1.A.3.d Waterway Transport	3.27	0.43	0.20	0.20	0.10	0.08	0.06	0.08	0.08	0.08	0.08	0.08	0.08
1.A.3.e Other types of transport	42.64	26.63	17.12	15.75	10.49	9.60	8.55	8.24	9.45	9.41	10.23	7.78	7.99

Changes in the structure of emissions from fuel combustion in the period of 1990-2021 in category 1.A.3 are presented in the diagram (Fig. 3.7).

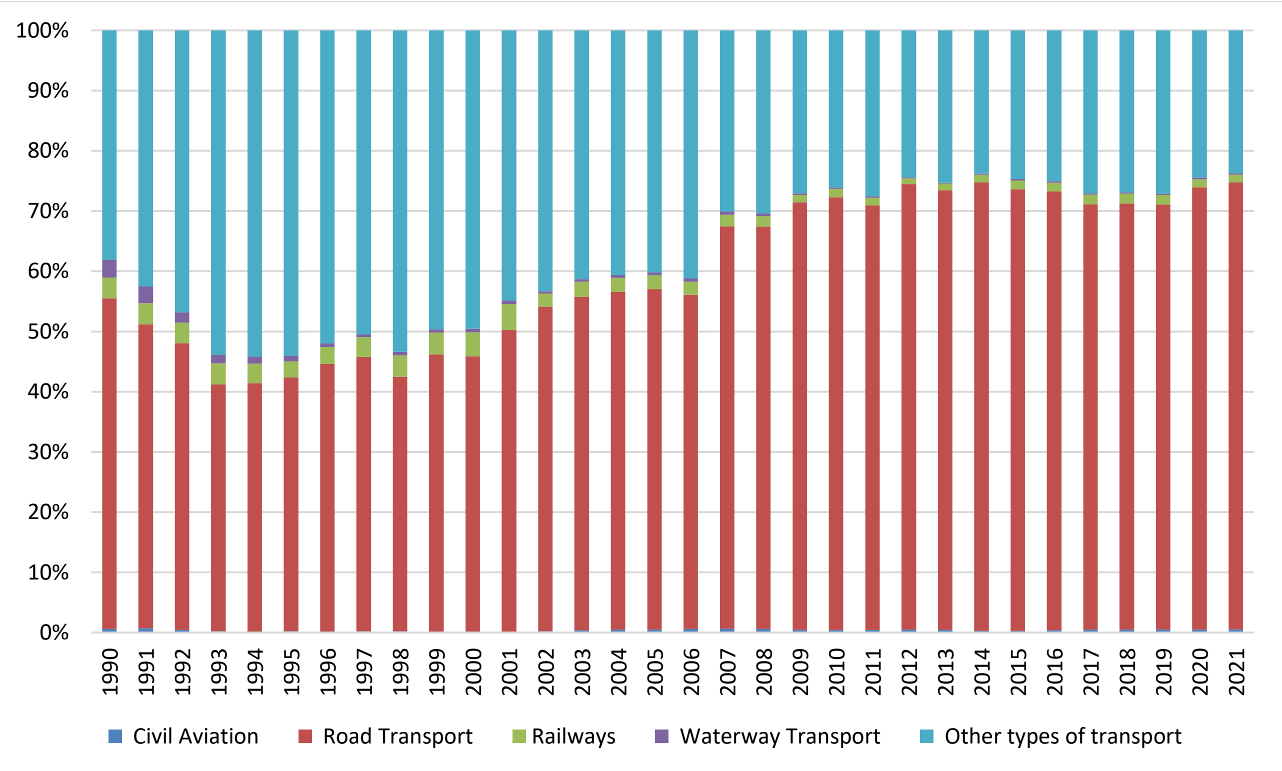


Fig.3.7. Changes in the structure of emissions from fuel combustion in category 1.A.3 "Transport", %

3.2.9.2 Methodological Issues

Activity data of fuel consumption by CRF category at mobile fuel combustion for 2021 are presented in Table A2.3.

Because of absence of some statistical information for 2021 the missing data were calculated on the basis of 2020 data using such drivers as import of fuels for categories 1.A.3.b and 1.A.3.e.ii and NG consuming for pipeline NG transportation for category 1.A.3.e.i. GHG emissions in 2021 in categories 1.A.3.c and 1.A.3.d are assumed to be equal to GHG emissions in 2020.

3.2.9.2.1 Civil Aviation (CRF category 1.A.3.a)

This category includes emissions from combustion of fuel used by civil aviation aircrafts and does not include emissions from fuel used by ground transport and stationary combustion plants at airports.

Emission estimation was conducted separately for aircraft equipped with jet and turboprop engines, which use jet fuel and those equipped with piston engines, in which aviation gasoline is used.

For more details on the technique of estimating GHG emissions from air transport, as well as the raw data, see Annex A2.7.

GHG emissions from domestic aviation in 2021 amounted to 189,60 kt of CO_2-eq, which is 16.5% higher than in 2020 and 72.21% lower than in 1990. For trends on GHG emissions from domestic and international aviation see Fig. 3.8.

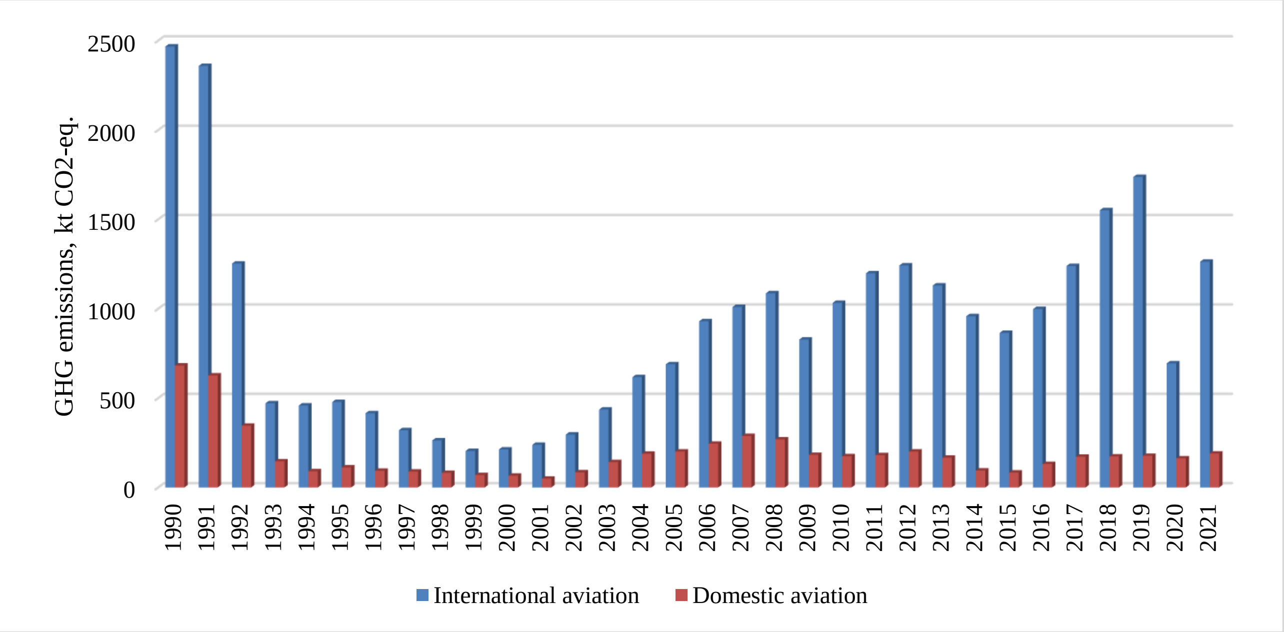


Fig. 3.8. GHG emissions from domestic and international aviation, 1990-2021

Estimation of CO_2 emissions from jet kerosene was held under the method corresponding to Tier 3; of CH_4 and N_2O – Tier 2; from aviation gasoline– to Tier 1, in accordance with [1]. The departure database (DDB) was provided by State enterprise of air traffic services of Ukraine.

3.2.9.2.2 Road Transportation (CRF category 1.A.3.b)

This category includes emissions from combustion of fuel by road transport, including vehicles owned by individuals.

In category 1.A.3.b "Road Transport", GHG emissions in 2021 amounted to 24.98 Mt of CO_2-eq., which is 6.9% higher than the same indicator in 2020, and decreased by 59.3% compared with 1990. GHG emissions, as well as their structure by fuels used are presented in Fig. 3.9.

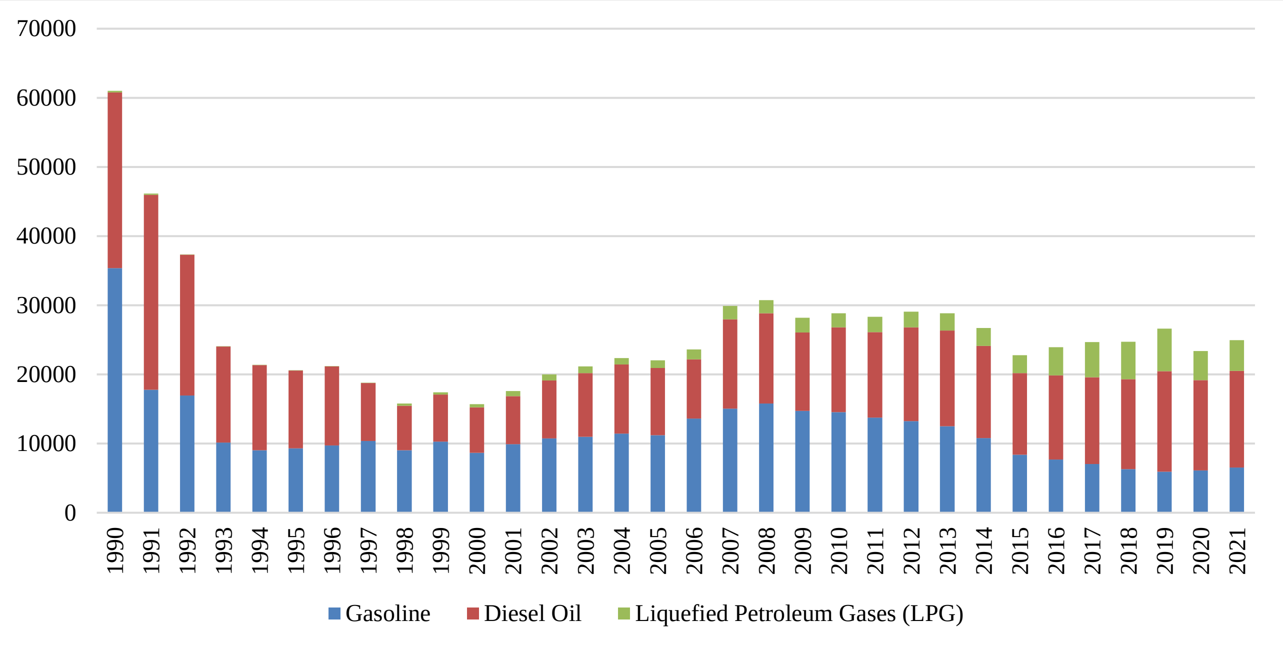


Fig. 3.9. GHG emissions in category 1.A.3.b "Road Transport" by fuels, for 1990-2021, kt of CO_2-eq.

Emissions in the category for the entire time series of 1990-2021 were calculated based on data on energy use of fuels according to form 4-MTP, as well as on data on sale of gasoline and gas oil to population through the network of petrol stations [16-29] taking into account the analytical study [14] using the balance sheet method and the national carbon content coefficients for gasoline, diesel and LPG which corresponds to Tier 2 for CO_2 emissions and Tier 1 for other gases according to [1]. More details on the methodological aspects used in the categories are described in Annex A2.4.2 and A2.6.3.

This approach to GHG inventory in category is due to the fact that national energy statistics is the only reliable source of data, allowing properly allocate data on use of fuels in motor vehicles without distorting the balance of different types of fuels.

Due to the changes in the form 4-MTP in 2016 the fuel volumes for 2016 - 2021 were calculated by surrogate method on the basis of 2015.

National circumstances for 2014 - 2021 are provided in Annex A2.10.

3.2.9.2.3. Railways (CRF category 1.A.3.c)

This category includes emissions from combustion of fuel consumed for thermal traction of railway rolling stock. In Ukraine diesel fuel is used as the fuel for locomotives. This category does not include emissions associated with production of the electricity needed for electric train drives.

In 2021, emissions in the category amounted to 0.42 Mt of CO_2-eq., which is equal to that in 2020, and to the baseline 1990 – decreased by 9.1 times.

Emissions in this category were evaluated using the procedure described in Annex 2.4. The method for estimating emissions corresponds to Tier 2 for CO_2 emissions from diesel combustion and tier 1 – for non-CO_2 gases in accordance with [1].

It is worth noting that in 2009 there was a precipitous reduction of emissions in the category (during the year - by 40%), due to the effects of the global economic crisis of 2008 – a decrease in industrial production and, accordingly, decline in demand for freight transportation.

National circumstances for 2014 - 2020 are provided in Annex A2.10.

3.2.9.2.4 Navigation (CRF category 1.A.3.d)

This category includes emissions from combustion of fuel consumed for propulsion drives of sea and river vessels. This category includes emissions from enterprises assigned with code designation H50 "Waterway Transport".

GHG emissions from bunker fuels used for sea transport are not included in the total emissions and are considered as reference data.

The distribution of fuels for domestic transportation was performed based on the formula:

$$FC_{1.A.3.d} = FC_{H50} \cdot k_{1.A.3.d}; \quad (3.3)$$

Where:

$FC_{1.A.3.d}$ is consumption of fuels by domestic waterway transport (gasoil, fuel oil), tons;

FC_{H50} - consumption of fuels by TEA H50 "Water Transport" for transportation needs (gasoil, fuel oil), tons;

$k_{1.A.3.d}$ - the factor of fuel distribution into coastal transportation, in relative terms, which is defined by the following expression:

$$k_{1.A.3.d} = \frac{PR_h + PS_h}{PR + PS}; \quad (3.4)$$

Where:

PR_h is the volume of cargo transportation by domestic river transport, kt;

PSh is the volume of cargo transportation by domestic sea transport, kt;

PR - total volume of cargo transportation by river transport, kt;

PS - total volume of cargo transportation by sea transport, kt.

The volumes of cargo transportation were taken from statistical yearbooks [16-29].

In 2021, emissions in category amounted to 83,19 kt of CO_2-eq which is equal to that in 2020 and to the baseline 1990 - having decreased by 39.3 times. GHG emissions from domestic and international navigation for 1997 - 2021 are presented in the Fig.3.10.

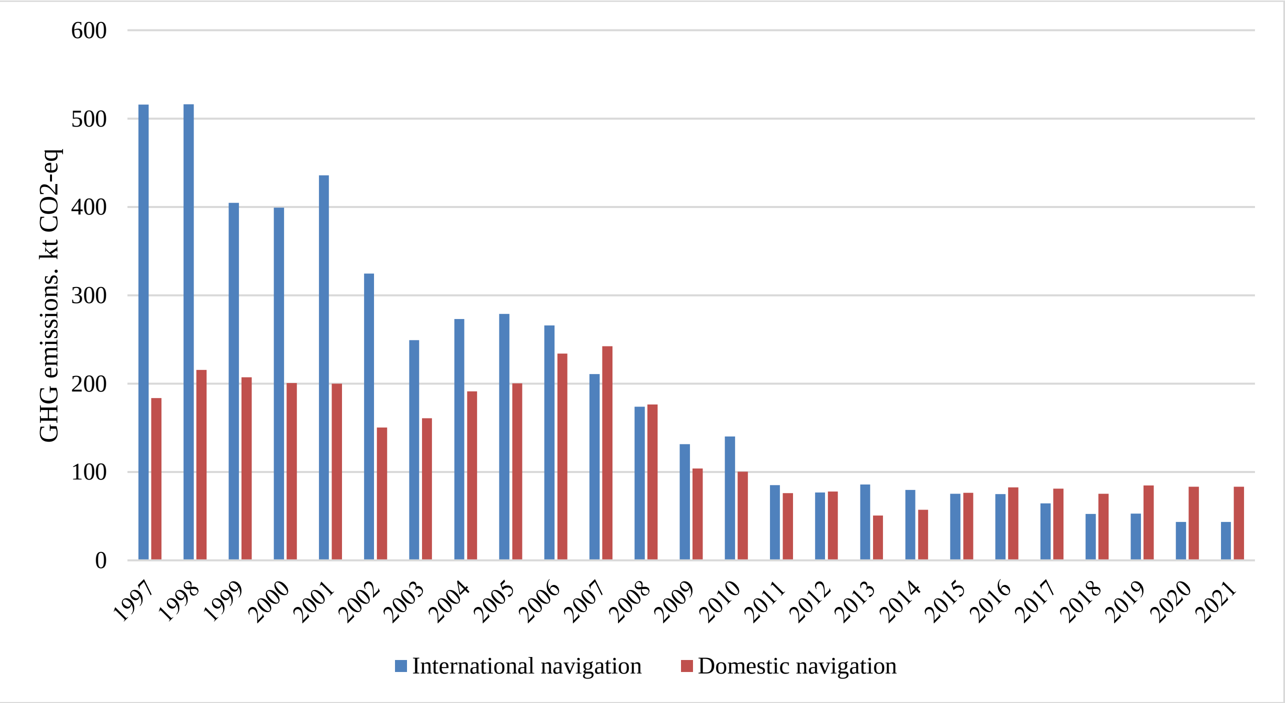


Fig. 3.10.GHG emissions from domestic and international navigation, 1997-2021

The correlation between cargo turnover and GHG emissions are presented in the Fig.3.11.

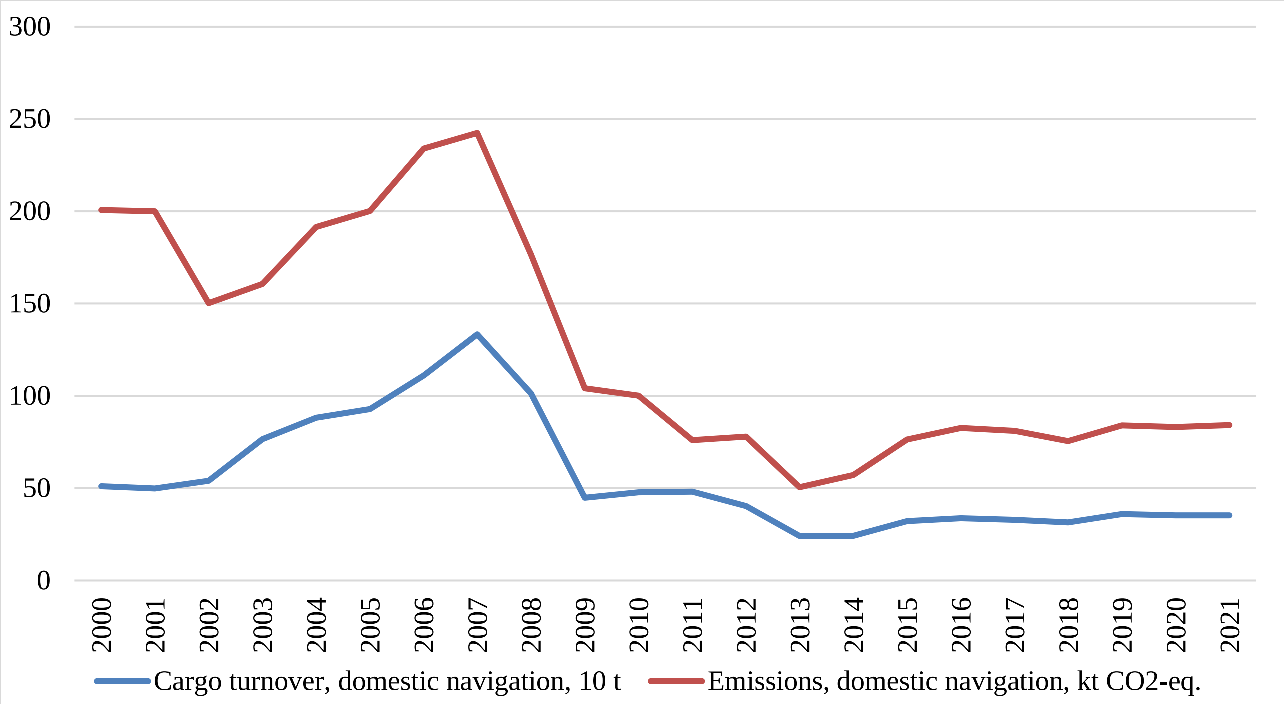


Fig. 3.11The fluctuations in navigation were due to fluctuations in national economy.

National circumstances for 2014 – 2021 are provided in Annex A2.10.

3.2.9.2.5 Other Types of Transportation (CRF category 1.A.3.e)

This category includes emissions from combustion of natural gas by drives of gas pumping units of compressor stations of main gas pipelines, as well as activities of off-road vehicles.

Pipeline Transportation (CRF category 1.A.3.e.i). This sub-category includes emissions from combustion of natural gas by drives of gas pumping units of gas mains. The volume of this gas was determined according to data of the SC "Ukrtransgaz", NJSC "Naftogaz" and SSSU.

In 2021, emissions in the sub-category amounted to 1,63 Mt of CO_2-eq., having decreased with respect to 2020 by 10.76% and to the baseline 1990 – decreased by 82.49%.

Estimation of CO_2 emissions in the sub-category was held under the method corresponding to Tier 2 in accordance with [1] and for non-CO_2 gases - to Tier 1.

Off-Road Transport (CRF category 1.A.3.e.ii). This category includes emissions from fuel combustion for the drive of the so-called in-house transport of all sectors of the economy. In-house transport, in particular, includes heavy vehicles of mining enterprises.

This category also includes emissions from fuel combustion in drives of combines, tractors, and other machinery used in field of agricultural work, regardless of the sectors of the economy in which they are used.

In 2021 emissions in the sub-category amounted to 6.36 Mt of CO_2-eq., which is 6.9% higher than the same indicator in 2020, and to the baseline 1990 - decreased in 5.23 times.

Estimation of CO_2 emissions in the sub-category was held under the method corresponding to Tier 2 for CO_2 emissions from gasoline, diesel and LPG combustion and Tier 1 – for non-CO_2 emissions in accordance with [1] for all greenhouse gases.

Due to the changes in the form 4-MTP in 2016 the Off-Road Transport fuel volumes were calculated by surrogate method on the basis of 2015. National circumstances for 2014 - 2021 are provided in Annex A2.10.

3.2.9.3. Uncertainties and Time Series Consistency

Uncertainties of activity data and emission factors are present in Table 3.11.

Table 3.11. Uncertainties of activity data and emission factors in category 1.A.3 "Transport"

Type of fuel	Uncertainty of activity data. %	Uncertainties of emissions factors. %		
		CO_2	CH_4	N_2O
Liquid fuel	17.60	4.7	15.43	10.95

Estimated total GHG emission uncertainty in this category is 17.1%.

The most significant impact on the overall uncertainty of GHG emission estimation in this category is produced by CO_2 emission estimation uncertainty in the category 1.A.3.b "Road Transport".

3.2.9.4 Category-specific QA/QC Procedures

The general quality control procedures under [1] were applied. The analysis of forms of statistical reporting containing the original data for GHG emission calculation was conducted together with the SSSU specialists.

Methodology issues in category 1.A.3.b "Road Transport" were analyzed by specialized experts from SE "DerzhavtotransNDIproject".

3.2.9.5 Category-specific Recalculations

In this category, no recalculations were made.

3.2.9.6 Category-specific Planned Improvements

The expecting recovery of road transport data base will give the opportunity to carry out appropriate calculations according to COPERT program.

3.2.10 Other Sectors (CRF category 1.A.4)

3.2.10.1 Category Description

In 2021, GHG emissions in category 1.A.4 "Other Sectors" amounted to 19.08 Mt of CO_2-eq., which is equal to that in 2020, while in comparison with the baseline 1990 decreased by 81.3%.

The key source of emissions in 2021 is sub-category 1.A.4.b "Residential Sector", which accounted for approximately 94.6% of the total emissions (see Table 3.13).

Table 3.13. GHG emissions in category 1.A.4 "Other Sectors", Mt of CO_2-eq.

Emission category	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019	2020	2021
1.A.4 Other Sectors total, including:	102.01	66.35	40.50	42.55	39.46	38.99	32.73	28.12	30.78	27.99	22.32	19.08	19.08
1.A.4.a Commercial/Institutional Sector	38.73	23.83	6.54	4.65	2.73	2.60	1.66	1.90	2.88	2.51	2.15	0.66	0.66
1.A.4.b Residential Sector	59.46	41.53	33.80	37.72	36.52	36.02	30.77	25.80	27.48	25.09	19.85	18.06	18.06
1.A.4.c Agriculture/Forestry/Fishery/Fishing	3.82	0.99	0.16	0.18	0.21	0.37	0.30	0.42	0.42	0.38	0.32	0.37	0.37

The significant decreasing of emissions in the Commercial/Institutional and Residential sectors during 1990-2000 is due to the collapse of the USSR, need to save energy and decrease of population. Then the fluctuations are connected with economic crisis and migration and decline of population.

Changes in the structure of emissions from fuel combustion in category 1.A.4 are presented in the diagram (Fig. 3.12).

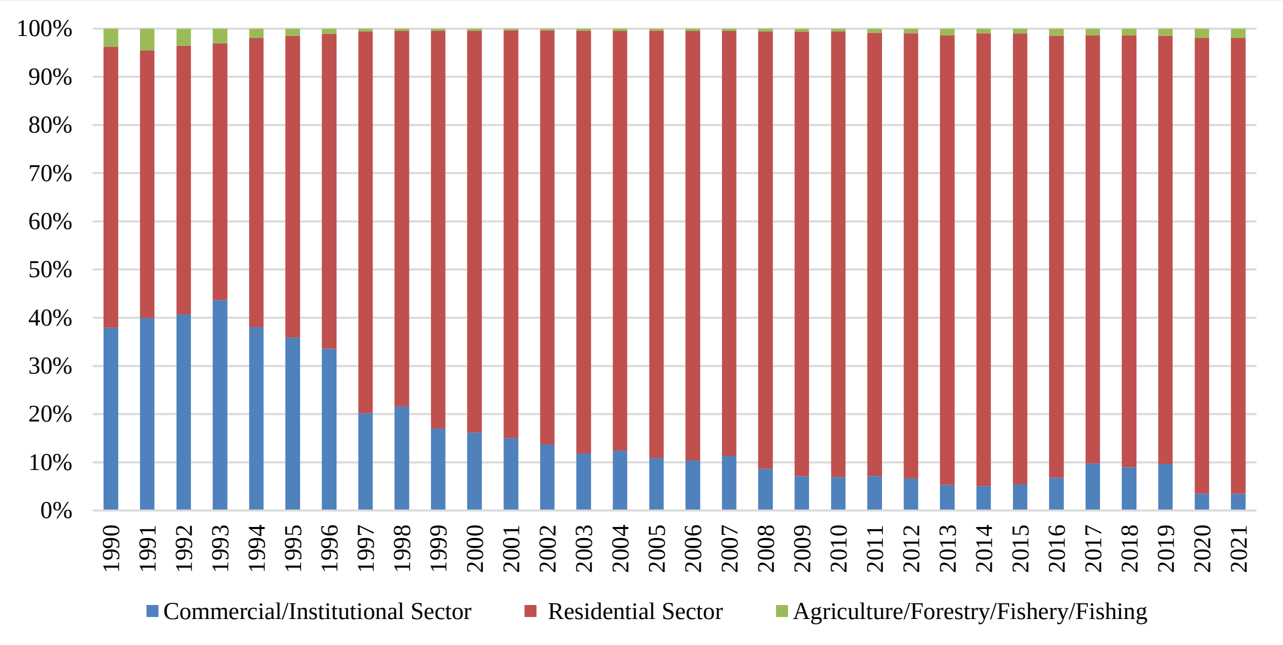


Fig. 3.12. Changes in the structure of emissions from fuel combustion in category 1.A.4 "Other Sectors", %

Changes in the structure of fuel consumption in subcategory 1.A.4.b "Residential Sector" are presented in the diagram (Fig. 3.13).

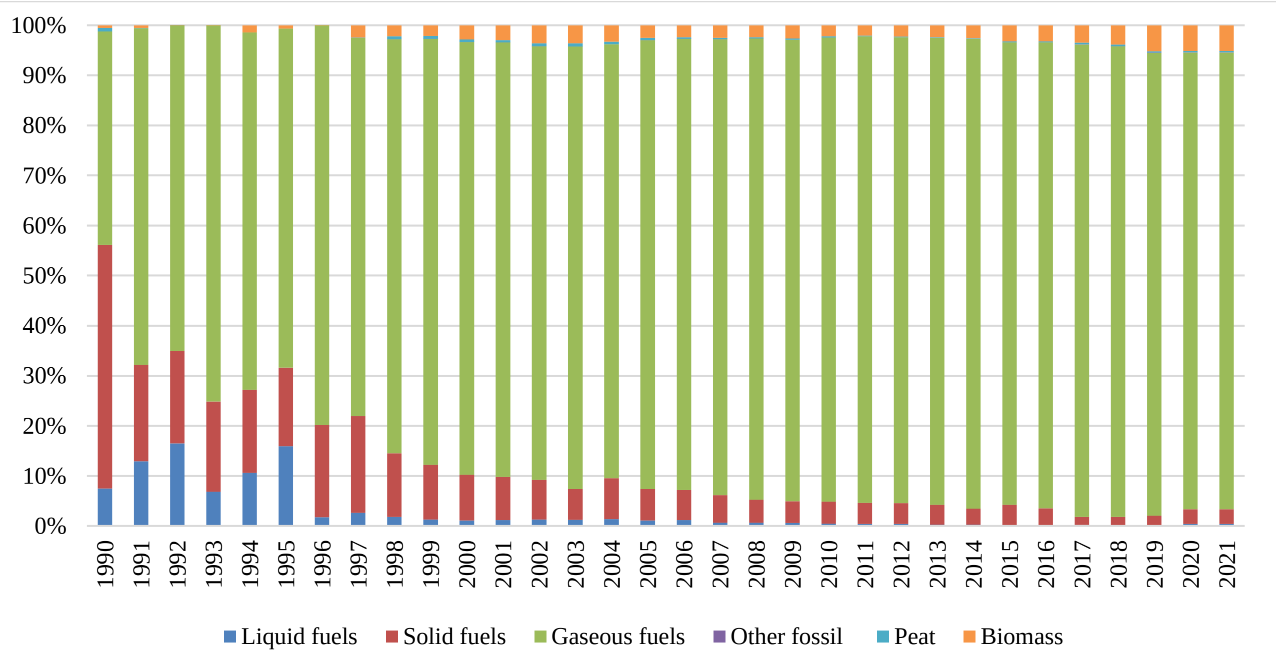


Fig. 3.13. Changes in the structure of fuel consumption in subcategory 1.A.4.b "Residential Sector"

3.2.10.2 Methodological Issues

Emissions related to fuel combustion were evaluated using the procedure described in Annex 2. National circumstances for 2014 - 2021 are provided in Annex A2.10.

Because of absence of appropriate statistical information for 2021 GHG emissions in 2021 in these categories are assumed to be equal to GHG emissions in 2020.

3.2.10.2.1 Commercial/Institutional Sector (category 1.A.4.a)

The GHG emissions were estimated on the basis of data on the amount of fuel burned used for own needs by the business sector and public administration bodies, which includes activities of hotels and restaurants, financial institutions, governmental bodies, education facilities, etc. A detailed algorithm of source data determination is presented in Annex A2.

3.2.10.2.2 Residential Sector (category 1.A.4.b)

The GHG emissions were estimated on the basis of data on the amount of fuel used for domestic needs of population. GHG emissions from individuals' vehicles are included in category 1.A.3.b "Road Transport". A detailed algorithm of source data determination is presented in Annex A2.

3.2.10.2.3 Agriculture/Forestry/Fishery/Fishing (category 1.A.4.c)

This category includes emissions from stationary fuel combustion in industrial production in agriculture, forestry and fisheries. A detailed algorithm of source data determination is presented in Annex A2.

3.2.10.3 Uncertainties and Time Series Consistency

Uncertainties of activity data and emission factors are present in Table 3.14.

Table 3.14. Uncertainties of activity data and emission factors in category 1.A.4 "Other Sectors"

Type of fuel	Uncertainty of activity data, %	Uncertainties of emissions factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	8.16	2	150	500
Solid fuel	13.14	5	150	500
Gaseous fuel	11.79	5	150	500
Other types of fuels	30.00	5	150	500
Biomass	30.44	5	150	500

Quantification of the uncertainty was performed on the basis of the above uncertainty values of activity data and emission factors according the methodology of [1].

Estimated total GHG emission uncertainty in this category is 12.7%.

The most significant impact on the overall uncertainty of emissions in this category is produced by CO_2 emission uncertainty in category 1.A.4.b "Residential Sector", mainly the uncertainty in consumption of gaseous fuel. This is due, primarily, to absence of individual meters at lots of private house-holds.

3.2.10.4 Category-specific QA/QC Procedures

The general quality control procedures [1] were applied, plus cooperation with the SSSU was established, and analysis of forms of statistical reporting containing the original data for GHG emission calculation was conducted together with the SSSU 's specialists.

3.2.10.5 Category-specific Recalculations

In this category, no recalculations were made.

3.2.10.6 Category-specific Planned Improvements

In this category, no improvements are planned.

3.2.11 Unspecified Categories (CRF category 1.A.5)

3.2.11.1 Category Description

This category includes GHG emissions from sources not included in the other categories. In 2021, GHG emissions in category 1.A.5 "Unspecified Categories" amounted to 0.38 Mt of CO_2-eq., which is 14.5% lower than in 2020 and to the baseline 1990 – increased by 3.6 times (see Table 3.16).

Table 3.16. Greenhouse gas emissions in category "Unspecified Categories", kt of CO_2-eq.

Cate-gory	1990	1995	2000	2005	2010	2012	2014	2016	2017	2018	2019	2020	2021
1.A.5	105.93	57.27	59.00	84.44	31.60	119.24	397.74	529.75	533.77	475.64	360.17	449.59	384,48

3.2.11.2 Methodological Issues

Emissions related to fuel combustion were evaluated using the procedure described in Annex 2. Category 1.A.5 "Unspecified Categories" includes emissions from use of fuels by the Armed Forces of Ukraine.

3.2.11.3 Uncertainties and Time Series Consistency

Uncertainties of activity data and emission factors are present in Table 3.17.

Table 3.17. Uncertainties of activity data and emission factors in category 1.A.5 "Unspecified Categories"

Type of fuel	Uncertainty of activity data, %	Uncertainties of emissions factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	5	2	150	500

Estimated total GHG emission uncertainty in this category is 5.39%.

3.2.11.4 Category-specific QA/QC Procedures

The general quality control procedures stipulated in [1] were applied.

3.2.11.5 Category-specific Recalculations

No recalculations were performed in the category.

3.3 Fugitive Emissions from Fuels (CRF category 1.B)

Fugitive emissions from fuels are the result of GHG leakages during extraction, treatment, transportation, storage, and consumption of fossil fuels. This category also includes emissions from flaring of hydrocarbons. In 2021 emissions in category 1.B "Fugitive Emissions from Fuels" accounted for 50.36 Mt of CO_2-eq. or about 24.0% of the total emissions in the "Energy" sector, and decreased by 60.5% compared to 1990. From 2020, emissions in this category have increased by 0.12%. More detailed information is presented in Fig. 3.14.

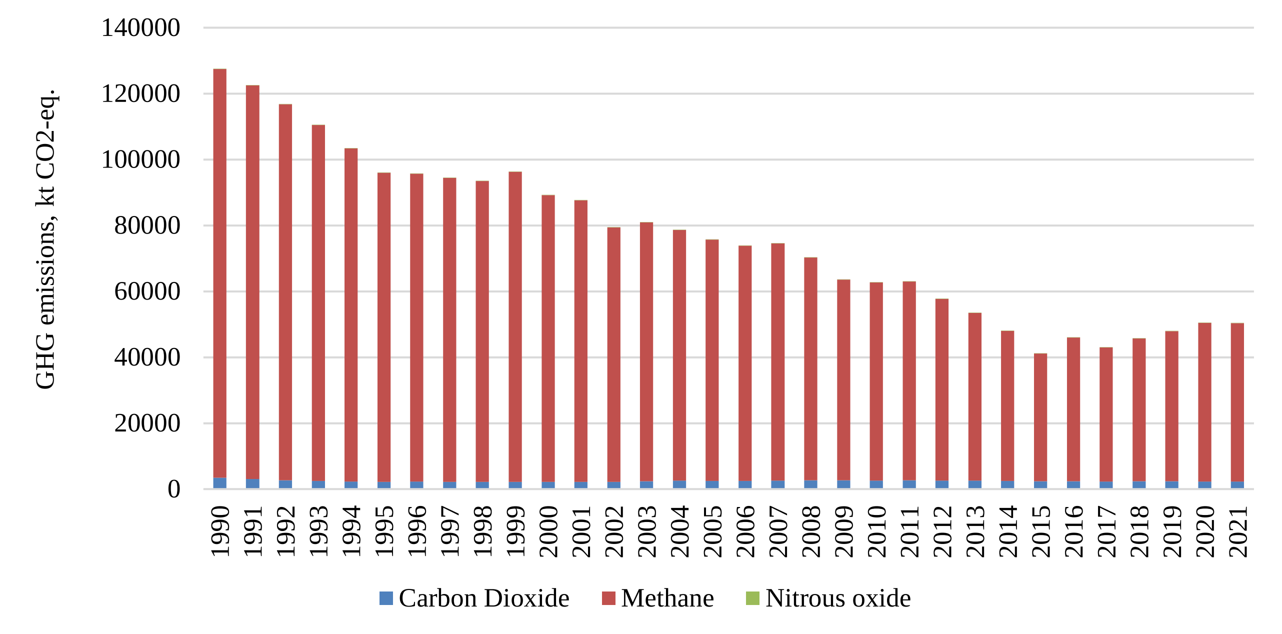


Fig. 3.14. Greenhouse gas emissions in category 1.B "Fugitive Emissions from Fuels" (sectoral approach)

In 2021, 22.2% of emissions in the category 1.B "Fugitive Emissions from Fuels" were in the category "Solid Fuels", and 77.8% - in the category "Oil and Natural Gas" (see Table 3.18).

Table 3.18. Emissions in category 1.B "Fugitive Emissions from Fuels", Mt CO_2-eq.

Emission category	1990	1995	2000	2005	2011	2012	2014	2016	2017	2018	2019	2020	2021
1.B Fugitive Emissions from fuels (total), including:	127.47	96.02	89.22	75.70	62.99	57.69	47.98	45.96	43.00	45.71	47.93	50.42	50.36
1.B.1 Solid fuels	62.38	38.26	32.96	25.94	23.74	24.05	18.69	16.62	13.00	13.13	12.68	10.93	11.17
1.B.2 Oil and Natural Gas	65.09	57.77	56.26	49.76	39.25	33.64	29.29	29.34	30.00	32.58	35.26	39.49	39.19

3.3.1 Solid Fuels (CRF category 1.B.1)

3.3.1.1 Category Description

The key source of emissions in category 1.B.1 "Solid Fuels" is methane emissions that occur during extraction of coal at mines.

3.3.1.2 Coal Mining and Handling (CRF category 1.B.1.a)

3.3.1.2.1 Underground Mines

In order to improve accuracy of GHG emission estimation in this category, until 2014 Makiivka State Scientific and Research Institute for Safety in Mines (MakNDI) was involved and performed research work for the purpose of inventory of GHG emissions in the coal industry. Inventory of methane emissions at Ukrainian mines was carried out based on results of measuring the actual flow rate of methane in outgoing air flows of gas mines and the production rate of methane captured by vacuum pump plants (VPP) on the surface, which corresponds to Tier 3 [1].

1.B.1.a.1.i Mining Activities. The volume of coal bed methane (including recovery and flaring) from 1990 to 2000 are taken from [8]. For 2003 - 2012 information is taken from scientific research work [4] and shown in Table 3.19, for 2001 and 2002 - interpolation based on 2000 and 2003 and data on coal production. For calculation of emissions from 2013 to 2021 the surrogate data method was used based on 2012 and data on coal production for 2013 – 2021 taken from the statistical form 1-P.

In 2021, methane emissions from underground mining activities amounted to 438.49 kt and compared to 1990 they decreased by 82.3 %, and higher by 2.19% than the same indicator in 2020.

The leading pace of GHG emission reduction in this category in comparison with raw coal production is explained by a decrease in the proportion of active methane containing mines, as well as due to execution of Joint Implementation projects (JIP).

Table 3.19 provides detailed information on utilization of mine methane in Ukraine during 2003-2012.

1.B.1.a.1.ii Post-Mining Activities. In the process of coal production and transportation, methane is produced. The major part of it is released from the exposed surface of the mined bed (40-60%) and chipped coal into the workspace of stope and conveyor (runway) drift (20-30%).

The amount of released methane is registered by stationary monitoring devices in outgoing streams of the stope and production area. The amount of methane released from chipped coal during its transportation from the production areas to the shafts is registered by control devices in outgoing air flows of mines.

Coal transportation onto the earth's surface at highly productive mines usually does not exceed 8 hours. Thus, methane emissions from coal taking place during its transportation to the surface are accounted for in the category "Mining Activities" (CRF category 1.B.1.a.1.i).

On the surface, methane continues releasing from coal, but measuring its production rate is not possible. According to [7], the coefficient accounting for the degree of degassing of chipped coal during the transportation time is determined by the formula:

$$k = aT^{в} \quad (3.5)$$

where:

T is the time of transportation (degassing) of coal chipped from the coal array, min.;

a,в - coefficients characterizing the gas release rate from chipped coal, *a* = 0.118, *в* = 0.25

The curve of the dependence of the degree of degassing of chipped coal and the transportation time shows that after 5156 min., i.e. 3.6 days, chipped coal is almost completely degassed. The key part (73%) of methane from the exposed surface of the coal bed developed is released during the first days after chipping of the array. Thus, the degree of coal grinding does not significantly influence the amount of methane released.

Anthracite coal with the release of volatile substances from 3.0 to 9.0% (coal brand A, PA) has a low, compared to other coals (coal brands T, OS, D, Zh, G) degree of gas release, so its degassing takes longer. Dependence of the degree of degassing of anthracite with the release of volatile substances from 3.0 to 9.0% on the transportation time has not been established to date [4].

The amount of methane emissions from coal after it is raised from the mine depends primarily on the following factors:

- the coal mass raised to the surface, tons;
- the natural and final methane richness of the coal, m3/ton of dry ash-free mass;
- the speed of the longwall's progress, m/day;
- the length of stay of chipped coal in the mine, hours;
- the duration of stay of chipped coal on the surface from the moment of raising to the surface till it is used, hours;
- humidity of coal raised from the mine, %;
- ash-content of coal raised from the mine, %.

The amount of methane emissions from coal in the period after its production wasn't controlled and calculated. According to [1], to calculate methane emissions in the period after coal production the amount of coal production should be multiplied by the corresponding emission factor. In 2001, Donetsk Expert and Technical Center (DETC) of the State Mine Surveillance Committee conducted a special study of the methane emission factor for the period after coal mining [8]. The general methane emission factor obtained as a result for all Ukrainian mines was 2.4 m3/t. Therefore, for estimation of methane emissions after coal mining at gas mines the emission factor of 2.4 m3/t is used in the inventory.

The amount of the post-mining methane emission factor set is close to the average value from the range recommended in [1].

Coal production is determined by multiplying the average daily production at gas mines of Ukraine by the number of working days per year in production, which is on average 354 days [4].

In 2021, post-mining methane emissions amounted to 48.2 kt and compared to 1990 they decreased by 77.4%, and is 2.25% higher than the same indicator in 2020.

1.b.1.a.1.iii Abandoned Underground Mines. After completion of coal mining, methane release from the rock array under mining operations phases out, but it may remain at a relatively high level for a long time. Therefor after cessation of mines, ventilation and filling (flooding) of shafts, gas may accumulate in worked-out spaces under certain geological conditions, creating excessive pressure in them. Methane gradually fills in all the worked-out space, up to the top horizon, and then starts penetrating through fissured rocks and abandoned mines to the surface, into buildings and constructions.

Inventory of methane emissions in mines of Ukraine was conducted by "State Makeevka Research Institute for Labor Safety in Mining" based on actual measurements of methane flows in outgoing air streams of gas mines and the rate of methane production captured by VPPs on the surface. For each gas mine, the data were taken from the orders establishing methane-based mine categories. The orders contain information about the actual average absolute mine methane content in view of captured methane in m^3/min., the average annual consumption of methane captured by VPPs in m^3/min., the average daily coal production in tons throughout the year. Calculation of CH_4 emissions from abandoned mines is calculated as the maximum total flow rate of methane measured in the course of the year (in m^3/min) restated as annual emissions based on 365 days/year.

For calculation of methane emission in this category for 2013-2021 the surrogate data method based on 2012 information was used. The amount of GHG emissions was evaluated being inversely to coal mined in 2013 - 2021 respectively.

Methane emissions from abandoned underground mines in 2021 amounted to 4.21 kt, which is 29.8% lower than in 1990 and 2.22% lower than in 2020.

3.3.1.2.2 Surface Coal Mining

In determining methane emissions from coal mines conducting surface coal mining, data of the companies were used, while emission factors were used by default in accordance with [1], namely:

- 1.2 m^3/t - for open-pit coal mining;
- 0,1 m^3/t - for coal processing and transportation (in open-pit mining).

3.3.1.3 Solid Fuel Transformation (CRF category 1.B.1.b)

This category includes CO_2 emissions associated with the loss of coke oven gas in the process of coke production.

Until 2013 the amount of coke oven gas losses was taken from column 6 "Losses caused by the lack of accounting, non-use, and due to other factors", section 5 "Losses of energy materials and products of oil refining in extraction, production, transformation, processing, transportation, and distribution" in form 4-MTP. For calculation emission in this category from 2014 to 2021 the surrogate data method was used based on 2013 and data on coke production for 2015 – 2021.

The carbon content is taken by default in accordance with [1], and the NCV - in accordance with statistical form 11-MTP.

Carbon dioxide emissions associated with loss of coke oven gas in production of coke in 2021 amounted to 165.36 kt, which is 60.2% lower than in 1990 and 2.2% lower than in 2020.

3.3.1.4 Other (CRF category 1.B.1.c)

This category includes CO_2 emissions associated with coal bed methane flaring. Table 3.19 provides detailed information on methane flaring and recovery (p. 3.2.7.2.3) in Ukraine during 2003-2012. The surrogate data method was used based on 2012. GHG emissions were estimated according to equation 5.2 (vol. 2, chap. 5) [1], on the basis of activity data indicated in the Table 3.19. In 2021 emissions in the sub-category amounted to 40.1 kt of CO_2-eq. which is 2.24% higher than the same indicator in 2020

Table 3.19. The amount of coal mine methane utilization in Ukraine, 2003-2012

#	Mine	Amount of utilized methane, thousand m^3/year										Note
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
1	named after O.Zasyadko		2220	2195	26.212	59.663	40.308	39.850	52571	36995	20317.77	Gasifier, gas station
2	named after V.Bazhanov SE "Makeevugol"	5890	6920	7605	6963	5676	6920	9061	10358	6649.34	3035.36	Boiler room
3	"Holodna Balka" SE "Makeevugol"	5210	5350	5730	6120	5030	5640	6600	4380	7094.74	7766.09	Boiler room
4	"Chaikino" SE "Makeevugol"	1920	2113	2420	2230	2970	2170	1790	410	1892.16	2295.69	Boiler room
5	named after S.Kirov SE "Makeevugol"	975	880	790	740	1120	1020	840	1800	944.19	205.83	Boiler room
6	"Kalynovska East" SE "Makeevugol"	-	-	-	710	-	-	-	-	-	-	Boiler room
7	named after M.Kalinin SE "DVEK"	1130	1130	1132	1132	1132	1132	1132	1132	1132	-	Boiler room
8	"Hrustalska" SE "Donbassantratsit"	2670	2670	2670	2670	2670	2670	2670	2670	2670	2670	Boiler room
9	"Scheglovska Hlyboka" m/a "Donbass"	2256	4177	4590	5530	7957	9131	12324	8704	8893	4481.76	Boiler room, shaft heating
								1400	1096	1259	3634	Flaring
											3278	Gasifier
10	No.22 "Komunarska" m/a "Donbass"							4630	6500	13100	13600	Flaring
								2189	3400	2600	4800	Gasifier
							300	683	1400	1500	3100	Boiler room
11	m/a "Pokrevske"		8919	18084	17013	20025	14805	14658	19473	11971	6207.2	Boiler room
										-	16153.4	Cogeneration
										5468	1287.3	Flaring
12	"Komsomolets Donbassa"						1522	5859	7569	8257	9194.16	Flaring
									2295	2613	2297.5	Boiler room
13	"Krasnolimanska"		602	2200	6058	6547	5279	8605	8910	10236	20068.31	Boiler room
14	"Sukhodolska Vostochnaya" PJSC "Krasnodonugol"				1564	2184	3194	2006	2705	12273	6587.17	Boiler, flaring
15	named after N. P. Barakov PJSC "Krasnodonugol"	5282	5282	6685	5945	5240	5134	3772	4916	4263	4755.14	Boiler room
16	"Molodogvardiiska" PJSC "Krasnodonugol"								580	2738	2879.1	Flaring
17	"Samsonovska Zapadnaya" PJSC "Krasnodonugol"							1140	2175	6470	6711.46	Flaring
18	"Stopovaya", PJSC "DTEK"										500	Boiler room
	Total, thousand m^3	25333	40263	54101	82887	120214	99225	119209	143044	149018.43	145825.24	

3.3.1.5 Uncertainties and Time Series Consistency

Continuous automatic monitoring of methane content in outgoing flows, periodic quality control of mine air and of correctness of its distribution in mine workings are performed at gas mines of Ukraine. At high-category and hazardous mines due to sudden outbursts, daily monitoring of gas release is conducted.

All VPPs, continuous automatic monitoring of methane content is conducted. Lots of mines are equipped with stationary captured gas mixture flow measurement devices.

The uncertainty of the results of methane emission from mines estimates is 14.84%. Uncertainty of carbon dioxide emissions is estimated as 10.55%.

The key contribution into the uncertainty is made by the uncertainty of estimates of methane emission at mining and handling, above all - the uncertainty of methane emission factors for underground coal mining.

3.3.1.6 Category-specific QA/QC Procedures

Common quality control procedures stipulated in [1] were applied, plus the advice and recommendations from line experts of the laboratory for degassing of coal mines at State Makeevka Research Institute for Labor Safety in Mining provided in 2014.

As part of the standard QA / QC procedures were refined data.

3.3.1.7 Category-specific Recalculations

In this category, no recalculations were made.

3.3.1.8 Category-specific Planned Improvements

In this category, no improvements are planned.

3.3.2 Oil and Natural Gas (CRF category 1.B.2)

Emissions in this category are related to leaks from exploration, extraction, transportation, processing, storage, and consumption of oil and natural gas.

3.3.2.1 Oil (CRF category 1.B.2.a)

3.3.2.1.1 Category description

In 2021, oil production in Ukraine was 1.7 Mt, which is 1.04% lower compared to the same indication for 2020.

There are 6 refinery enterprises in Ukraine. Up to 2009 they all worked. But during 2009-2012 five of them were stopped. Now only one refinery is working. The information on crude oil refined by this enterprise is confidential. So in view of inventory developers the default EFs are justified. In 2021 the volume of oil pumping amounted to 1648 kt. The volume of oil transit through the country amounted to 12700 kt and for the needs of the country – 3000 kt. The oil pipeline system includes 19 pipelines up to 1220 mm in diameter with a total length of 3507 km, 28 oil pumping stations (176 stations units), 79 in-service tanks and offshore oil terminal "Yuzhny". Input system capacity is 114 Mt/year, output – 56,3 Mt/year.

In 2021, GHG emissions in the category amounted to 1.71 Mt of CO_2-eq. The decrease with respect to 1990 is 59.8% and to 2020 - 1.2%.

3.3.2.1.2 Methodological issues

The data used for emission estimation in this category are presented in Table 3.20.

To estimate emissions in this category were used average Tier 1 default emission factors that presented in Table 3.21.

Oil transportation in Ukraine is carried out only by pipelines. So, the default emissions factors for transportation of oil by the pipeline were used according to [1]. The transformation of the amount of transported oil from mass units used by oil transportation enterprises into volumetric units was conducted based on the density of the Urals export blend - 0.865 t/m^3 and Azeri Light – 0.855 t/m^3.

CH_4 emissions from oil handling were taken by default according to [1]. To determine the carbon dioxide of oil handling, no factors are indicated in IPCC methodologies, so emissions in this category were not estimated.

The products of oil refining contain only negligible amounts of methane, therefore CH_4 emissions during transportation and distribution of petroleum products were not estimated. In the absence of approved IPCC methodologies, CO_2 emissions for this type activity were not estimated either.

Table 3.20. Activity data for emission estimation in the category "Oil" (1.B.2.a)

Year	Oil production, Mt	The volume of oil transportation through main pipelines, Mt	The volume of oil processing at refineries, Mt
1990	4.1	114.0	59.0
1991	3.9	94.9	54.6
1992	3.6	78.0	38.3
1993	3.3	66.9	23.5
1994	3.2	68.5	19.6
1995	3.0	65.3	16.9
1996	3.0	64.6	13.5
1997	2.9	64.1	12.8
1998	2.7	65.4	13.4
1999	2.7	65.2	11.0
2000	2.6	64.0	9.1
2001	2.6	63.6	16.1
2002	2.6	48.0	20.2
2003	2.8	56.7	21.9
2004	3.0	55.3	22.0
2005	3.1	46.7	18.4
2006	3.3	44.9	14.4
2007	3.3	50.9	14.1
2008	3.2	41.0	10.8
2009	2.9	38.5	11.2
2010	2.6	29.8	11.3
2011	2.4	25.2	8.9
2012	2.3	17.3	4.7
2013	2.2	17.6	3.7
2014	2.1	16.9	3.0
2015	1.9	16.8	2.7
2016	1.6	14.6	2.8
2017	1.5	16.0	3.6
2018	1.6	15.4	3.9
2019	2.1	15.5	3.8
2020	2.2	15.7	4.1
2021	1.7	15.7	4.1

Table 3.21. Emission factors for fugitive emissions from oil operation

CRF category	Category or sub-category	CO_2			CH_4			N_2O			NMVOC			Units of measure
		min	max	average	min	max	average	min	max	average	min	max	average	
1.B.2.a.1 Exploration	Well Drilling	1.0E-04	1.7E-03	9.0E-04	3.3E-05	5.6E-04	3.0E-04	ND			8.7E-07	1.5E-05	7.9E-06	Gg per 10^3 m^3 total oil production
	Well Testing	9.0E-03	1.5E-01	8.0E-02	5.1E-05	8.5E-04	4.5E-04	6.8E-08	1.1E-06	5.8E-07	1.2E-05	2.0E-04	1.1E-04	Gg per 10^3 m^3 total oil production
1.B.2.a.2 Production	Conventional Oil	1.1E-07	4.3E-03	2.2E-03	1.5E-06	6.0E-02	3.0E-02	NA			1.8E-06	7.5E-02	3.8E-02	Gg per 10^3 m^3 conventional oil production
1.B.2.a.3 Transport	Pipelines	4.9E-07			5.4E-06			NA			5.4E-05			Gg per 10^3 m^3 oil transported by pipeline
*1.B.2.a.4 Refining / Storage	Refining	-			90	1400	745	-			-			kg/PJ
	Storage Tanks				20	250	135							kg/PJ
1.B.2.c.1.i Oil	Conventional Oil / Venting	9.5E-05	1.3E-04	1.1E-04	7.2E-04	9.9E-04	8.6E-04	NA			4.3E-04	5.9E-04	5.1E-04	Gg per 10^3 m^3 conventional oil production
1.B.2.c.2.i Oil	Conventional Oil / Flaring	4.1E-02	5.6E-02	4.9E-02	2.5E-05	3.4E-05	3.0E-05	6.4E-07	8.8E-07	7.6E-07	2.1E-05	2.9E-05	2.5E-05	Gg per 10^3 m^3 conventional oil production

NA – Not Applicable. ND – Not Determined – in accordance with 2006 IPCC Guidelines
* - 1.B.2.a.4 – emission factors were taken by default according to 1996 IPCC Guidelines

3.3.2.2 Natural gas (CRF category 1.B.2.b)

3.3.2.2.1 Category description

The gas transportation system (GTS) of Ukraine consists of 33.39 thousand km of gas pipelines, including 20.89 thd km main pipeline and 12.20 thd km gas pipeline branches, 12 underground gas storages, 702 gas pumping units (including electric ones - 158) with the total capacity of 5.443 MW, a developed system of gas distribution and gas metering stations. The capacity of the gas transportation system at the inlet is 287.7 billion m^3 per year, at the outlet – 178.5 billion m^3 per year, including 140 billion m^3 per year to the European countries. The transportation volume according to international contracts in 2020 amounted to 55.8 billion m^3.

Natural gas production in 2021 amounted to 20993.04 billion m^3, which is 2.5% lower than the level of 2020. For 2021, the activity data about natural gas production was taken from the SSSU and taking into account the analytical study [26].

In 2021, GHG emissions in the category amounted to 37,27 Mt of CO_2-eq., the decrease with respect to 1990 is 38.24%, and 0.72% lower than the same indicator in 2020.

3.3.2.2.2 Methodological issues

The activity data used for emission estimation in this category are presented in Table 3.22.

To estimate emissions in this category average Tier 1 default emission factors were used that presented in Table 3.23.

Emissions from consumer leakages were calculated using the default factors according to 1996 IPCC Guidelines.

The methods of estimation of GHG emissions from transportation and distribution of natural gas are presented in section A2.8.

Table 3.22. Activity data for emission estimation in the category "Natural Gas" (1.B.2.b)

Year	Natural gas production, mln m^3	Household consumption of natural gas, bln m^3	Natural gas consumption by other consumers, bln m^3
2010	20528	17.8	38.2
2011	20651	17.7	39.3
2012	20492	17.3	35.3
2013	21313	20.0	25.9
2014	22048[1]	17.0	24.7
2015	21673[1]	12.3	20.0
2016	21741[1]	12.1	19.8
2017	21761[1]	12.3	18.5
2018	22558[1]	11.7	20.1
2019	21996	9.2	19.3
2020	21527	8.8	25.7
2021	20993	8.8	25.7

1 – in view of analytical study [26]

To calculate greenhouse gas emissions at transportation, distribution and consumption of natural gas, data on the composition of natural gas in the GTS of Ukraine received from PJSC "Ukrtransgaz", PJSC "Ukrgazvydobuvannya" and JSC "Transmission System Operator of Ukraine" (see A2.6.1, A2.8) were used.

Because of absence of some statistical information for 2021 GHG emissions in 2021 in categories 1.B.2.b.4) and 1.B.2.b.5) are assumed to be equal to GHG emissions in 2020 taking into account similar conditions in terms of production, consuming, COVID impact.

Table 3.23. Emission factors for fugitive emissions from gas operation

CRF category	Category or sub-category	CO_2			CH_4			N_2O			NMVOC			Units of measure
		min	max	average	min	max	average	min	max	average	min	max	average	
1.B.2.b.1 Exploration	Well Drilling	1.0E-04	1.7E-03	9.0E-04	3.3E-05	5.6E-04	3.0E-04	ND			8.7E-07	1.5E-05	7.9E-06	Gg per 10^3 m^3 total oil production
	Well Testing	9.0E-03	1.5E-01	8.0E-02	5.1E-05	8.5E-04	4.5E-04	-			1.2E-05	2.0E-04	1.1E-04	Gg per 10^3 m^3 total oil production
1.B.2.b.2 Production	Gas Production / Fugitives	1.4E-05	1.8E-04	9.7E-05	3.8E-04	2.4E-02	1.2E-02	NA			9.1E-05	1.2E-03	6.5E-04	Gg per 10^6 m^3 gas production
1.B.2.b.3 Processing	Gas Processing / Fugitives	1.5E-04	3.5E-04	2.5E-04	4.8E-04	1.1E-03	7.9E-04	NA			2.2E-04	5.1E-04	3.7E-04	Gg per 10^6 m^3 raw gas feed
*1.B.2.b.6 Other	Non-residential Gas Consumed	-			175000	384000	279500	-			-			kg/PJ
	Residential Gas Consumed	-			87000	192000	139500	-			-			kg/PJ
1.B.2.c.2.ii Gas	Gas Production / Flaring	1.2E-03	1.6E-03	1.4E-03	7.6E-07	1.0E-06	8.8E-07	2.1E-08	2.9E-09	1.2E-08	6.2E-07	8.5E-07	7.4E-07	Gg per 10^6 m^3 gas production
	Gas Processing / Flaring	1.8E-03	2.5E-03	2.2E-03	1.2E-06	1.6E-06	1.4E-06	2.5E-08	3.4E-08	3.0E-08	9.6E-07	1.3E-06	1.1E-06	Gg per 10^6 m^3 raw gas feed

NA – Not Applicable. ND – Not Determined – in accordance with 2006 IPCC Guidelines

* - 1.B.2.b.6 – emission factors were taken by default according to 1996 IPCC Guidelines

3.3.2.3 Venting and Flaring (CRF category 1.B.2.c)

The activity data used for emission estimation of venting at oil facilities and venting and flaring at gas facilities are the same as the activity data of 1.B.2.a and 1.B.2.b categories.

The default IEFs are taken from the Table 4.2.5. chapter 4 [1].

Emissions from venting at gas facilities are included in 1.B.2.b.4 "Transmission and storage" and 1.B.2.b.5 "Distribution".

3.3.2.4 Uncertainties and time-series consistency

The uncertainty of carbon dioxide emissions in the category is 10.81% and is associated with the uncertainty of factors of carbon dioxide emission from flaring at oil and natural gas production.

The uncertainty of methane emissions is 24.06% and is caused, above all, by the uncertainty of methane emission factors for consumption of natural gas by industrial consumers and power plants. The uncertainty of nitrous oxide emissions is 8.88%.

When estimating the uncertainty, data on the uncertainty of the emission factors presented in [1], were used, as well as data on the recommended ranges of emission factors [1].

3.3.2.5 Category-specific QA/QC procedures

The general quality control procedures stipulated in [1], were applied. In determining the national emission factors, comparison of data from various literary sources was held, consultations with independent experts in the gas industry, as well as with specialists of the leading companies operating in the oil and gas industry were conducted.

3.3.2.6 Category-specific recalculations

In this category, no recalculations were made.

3.3.2.7 Category-specific planned improvements

In this category, the developing of country-specific EFs for sub-categories 1.B.2.b and 1.B.2.c are planned.

3.4 Multilateral operations

The statistical reporting forms do not include data on activities of ex-territorial organizations. In this regard, in CRF category 1.D.2 "Multilateral Operations", it is indicated that this activity does not take place.

4 INDUSTRIAL PROCESSES AND PRODUCT USE (CRF SECTOR 2)

4.1 Sector Overview

GHG emissions in this sector include emissions from manufacture of industrial products, as well as from use of limestone, dolomite and soda in various technological processes. Emissions from fuel combustion for heat and electricity production in manufacture of industrial products are included into the "Energy" sector, except for emissions from the energy and non-energy components of use of coke for pig iron production (2.C.1) and the energy and non-energy components of use of natural gas in ammonia production (2.B.1), according to 2006 IPCC guidelines [1] (Block 1.1, Chapter 1, Volume 3). And indirect N_2O emissions calculated in accordance with 2006 IPCC guidelines [1] (Chapter 7.3, Volume 1).

GHG emissions was carried out for:

- Mineral Production and Use;
- Chemical Industry;
- Metal Production;
- Solvent and Non-Energy Product from Fuels Use;
- Electronic Equipment Production;
- Consumption of Substitutes for Ozone-Depleting Substances;
- Other Production and Use;
- Pulp Production and Food Industry.

GHG emission data for Ukraine are presented in Table 4.1

Table 4.1. GHG emissions in the sector Industrial Processes and Product Use

Gas	1990	2020	2021	Change, % compared	
				to 1990	to 2020
CO_2, kt	111084.50	48399.05	50000.68	-54.99	3.31
CH_4, kt CO_2-eq.	1 206.97	3455.74	3896.96	222.87	12.77
N_2O, kt CO_2-eq.	5 671.54	2352.47	2511.81	-55.71	6.77
HFC, kt CO_2-eq.	-	1751.50	1901.02	-	8.54
PFC, kt CO_2-eq.	235.819	-	-	-	-
SF_6, kt CO_2-eq.	0.007631	43.35	48.94	641195.00	12.9
Total direct action greenhouse gases, kt CO_2-eq.	118 198.83	56002.11	58359.4	-50.63	4.21
Total direct action greenhouse gases, % of total emissions (without LULUCF)	12.5	17.61	17.83	-	-
NO_x, kt	40.89	23.73	24.78	-39.40	4.41
CO, kt	69.36	34.58	36.45	-47.45	5.41
NMVOC, kt	460.01	105.87	111.15	-75.84	4.99
SO_2, kt	149.09	53.76	57.25	-61.60	6.49
Indirect N_2O, kt CO_2-eq.	4.89	2.84	2.96	-39.40	4.41

Fig. 4.1 presents diagrams for emissions of CO_2, CH_4, and N_2O, and Fig. 4.2 - in the major categories of the sector, respectively, in production and use of mineral products, production of chemical products, and manufacture of metals (including emissions of perfluorocarbons from aluminum production) and non-energy product from fuels, other nitrous oxide a hidrofluorocarbonates and sulphur hexafluoride use.

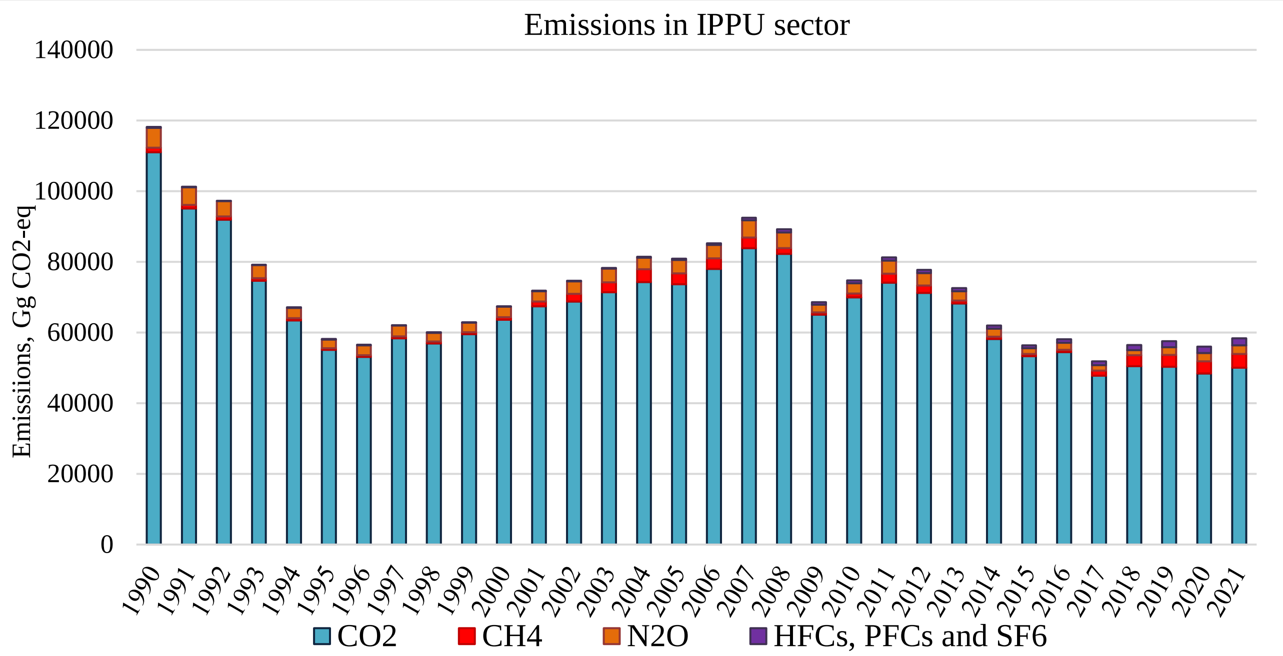


Fig. 4.1. Emissions of CO_2, CH_4, and N_2O in the sector Industrial Processes and Product Use, kt CO_2-eq

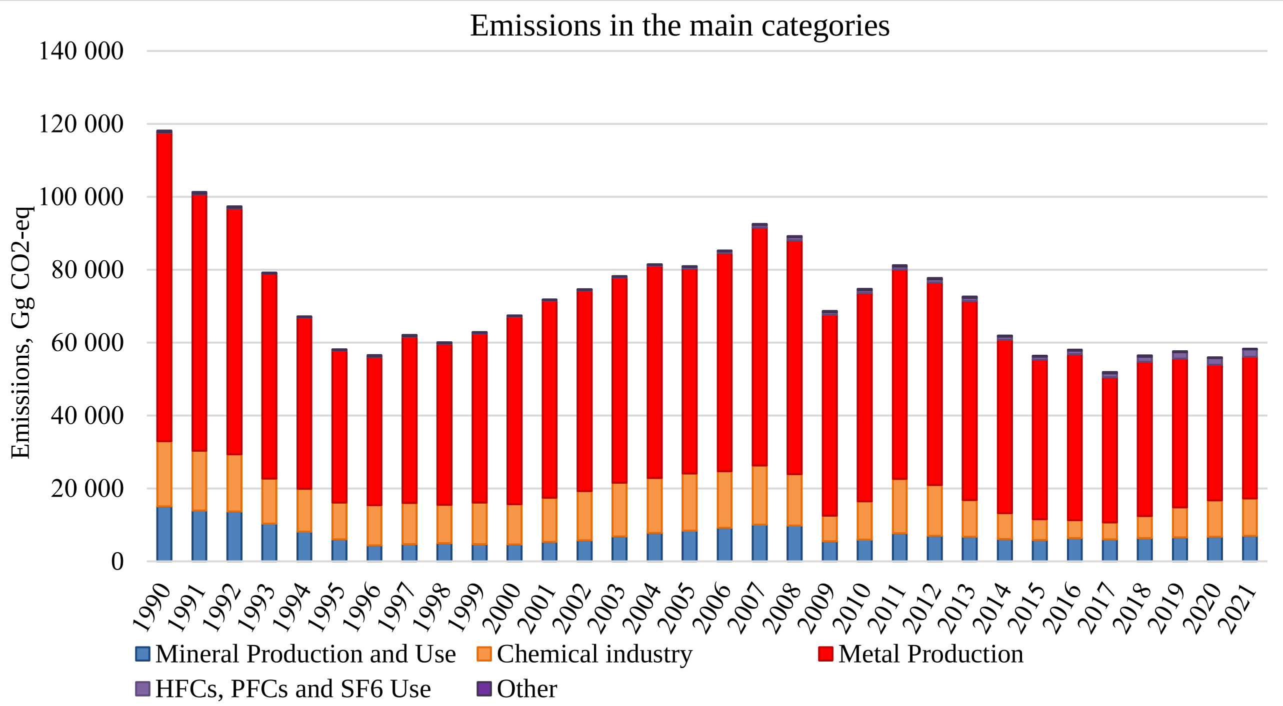


Fig. 4.2. Direct action greenhouse gas emissions in the major categories of the sector Industrial Processes and Product Use, kt CO_2-eq

Emissions in IPPU sector increased by 4.2% compared to last year, due to growth in industrial production in Ukraine by 1.1% according to the data of SSSU. The production in the metal industry increased by 5.2%, chemical industry decreased by 18.8%, and production of mineral products shows the growth by 7.5% which are the main sources of emissions in this sector. Emissions in the sector compared to the baseline year have decreased significantly due to a reduction in production output caused by the collapse of the USSR. Data on GHG emissions in the sector Industrial Processes and Product Use for the entire reporting period are shown in Table A3.1.1.1, Annex 3. Among all the categories, the greatest amount of CO_2 emissions is observed in production of pig iron and steel, ferroalloys, ammonia, cement, and lime. CH_4 emissions in the industrial sector are mainly associated with chemical products and pig iron production, and N_2O emissions - with nitric acid production and use of nitrous oxide for medical purposes.

Fig. 4.3 shows the precursor and SO_2 emission diagrams in the sector Industrial Processes and Product Use.

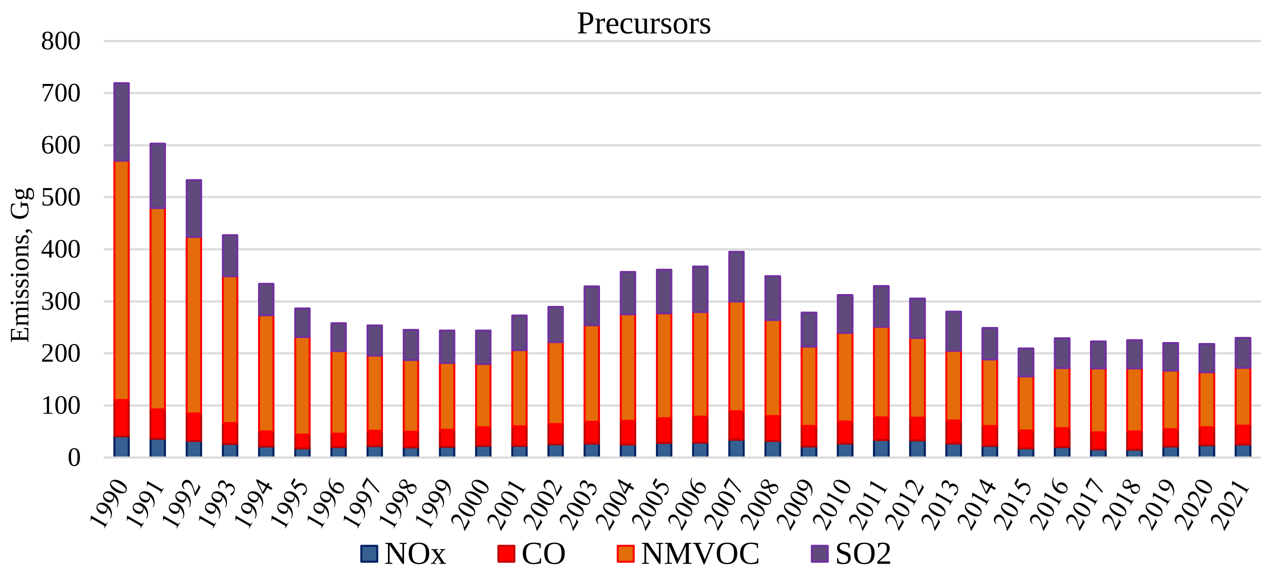


Fig. 4.3. Indirect action greenhouse gases and SO_2 emissions in the sector Industrial Processes and Product Use, kt

4.2 Mineral Industry (CRF category 2.A)

Emissions in this category are related with use of carbonate raw materials in the production and use of a variety of mineral industry products such as Cement, Lime, Glass and Ceramic production as well as Soda ash use. The main CO_2 emissions occurs in all this categories as well SO_2 and NMVOC from Cement and Glass production respectively. The key sources of CO_2 emissions are Cement and Lime production where the emmisions occurs from the processes related with clinker and lime production, the correlation of CO_2 emissions and amounts of these products production are shown on fig 4.4.

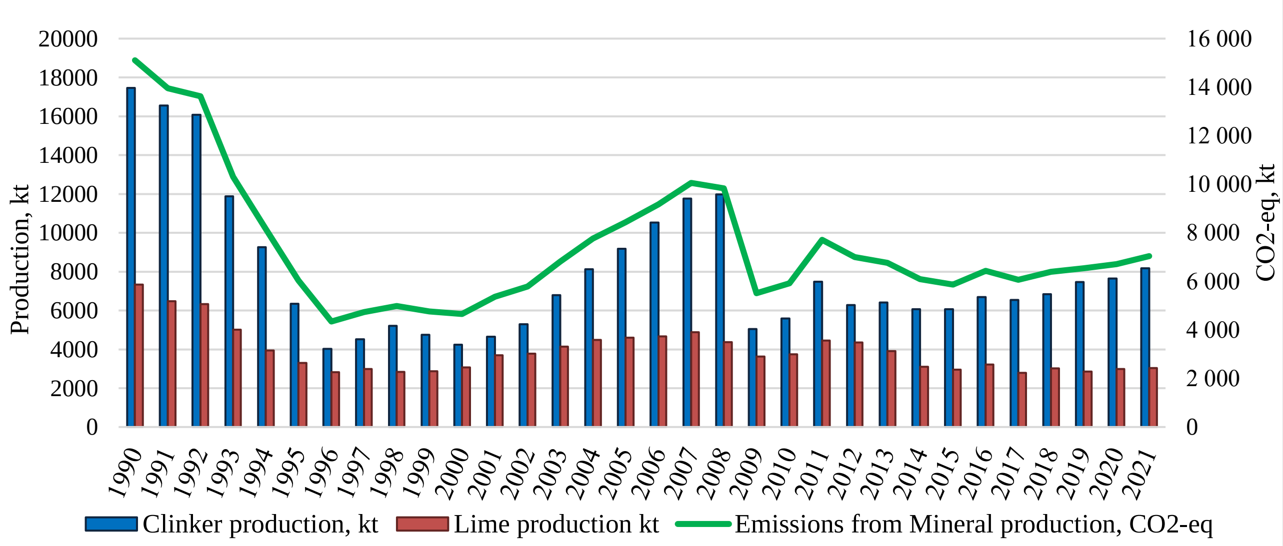


Fig. 4.4. CO_2 emissions from Key categories in Mineral industry, kt

Emissions from Glass and Ceramic production as well as from Soda ash use are not shown on the fig 4.4. due to the fact that their contributions to the emissions in Mineral industry category are not as significant as those indicated in graph above and they are not key categories.

The activity data collection, methodological issues as well as QA/QC procedures etc. by the categories included in Mineral industry are shown by each subcategory in relevant chapters.

4.2.1 Cement Production (CRF category 2.A.1)

4.2.1.1 Category description

Cement production is the main production of mineral products. Cement is a hydraulic binding substance that solidifies upon addition of water and is used in concrete for adhesion of sand and gravel. The raw material for cement production is the mixture of minerals consisting of calcium oxide, silicon oxide, aluminum oxide, and iron oxide. The basic composition of the raw material - limestone, chalk, marl, clay shale, or clay.

The main chemical processes in cement production start with dissolution of calcium carbonate at the temperature of 900˚C, resulting in formation of calcium oxide (CaO), and released carbon dioxide (CO_2). This is followed by the clinker production process: at high temperatures (typically 1400-1500˚C), calcium oxide reacts with silicon dioxide, aluminum oxide, and iron oxide forming silicates, aluminates, and calcium ferrites, which constitute the clinker. After that, clinker is rapidly cooled.

Carbon dioxide (CO_2) is released as a byproduct of the carbonate calcination reaction. In production of cement, SO_2 emissions also occurs.

Cement in Ukraine is produced by 12 enterprises-producers. Most of the enterprises-producers work basing on imported clinker. Projects that promote emission reduction have been implemented at a number of the enterprises-producers. These projects introduce use of alternative raw materials (ARM) that do not contain carbonates (use of blast furnace slag, peat, waste tires etc.) and transition to the dry production process, which entails a reduction of fuel consumption and of emissions from decarbonization.

The changing in the emissions and factors in 2012 - 2021 was due to decrease in use of non-carbonate raw material components in the production and the fact that some of the enterprises use imported clinker. Table 4.2 shows the basic data on the results of GHG inventory in cement production.

Table 4.2. The basic data on the results of GHG inventory in cement production in 2021

Category code	**2.A.1**	
Cement production, kt	11403.4	
Clinker production, kt	8175.13	
CaO content in clinker, %	65.94	
MgO content in clinker, %	1.34	
Gases	CO_2	SO_2
Emissions, kt	4338.53	3.42
Change in emissions compared to the previous year,%	6.73	12.52
Change in emissions compared to the baseline year,%	-53.85	-49.83
Emissions, % of the total emissions in the sector	8.68	5.97
Emissions, % of the total direct action GHG emissions in the sector	7.43	
Key category ("l" - level, "t" - trend)	L/T	
Detail level (Tier)	2	1
Correction factor for cement kiln dust, p.u.	1.02	
Emission factor, t/t	0.520	0.0003
Conditioned emission factor, t/t	0.531	
Method for determination of the emission factor	CS	
Uncertainty of activity data, %	1.7	
Uncertainty of the emission factor, %	5.408	
Uncertainty of the emission estimation, %	5.734	

Activity data, emission factors, and GHG emissions throughout the time series in this category are shown in Table A3.1.1.2, Annex 3.1.1.

4.2.1.2 Methodological issues

For estimation of CO_2 emissions, the emission estimation method using data of the amount of produced clinker (Tier 2 method) [1] was used on the basis of data obtained from enterprises-producers and Ukrainian Association of Enterprises and Organizations of Cement Industry "Ukrcement". Data about cement production were obtained from SSSU [2]. For 2014 - 2021, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of cement and clinker production. Emission factor was derived, based on Tier 2 method, taking into account CaO(65.94%) and MgO(1.34%) content of the clinker and, as well as the fraction of CaO and MgO of non-carbonate raw material components (1.35 and 0.0%) for 2021 respectively which were obtained from enterprises-producers. Cement kiln dust correction factor (CKD) was determined by default according to 2006 IPCC Guidelines [1].

Decrease in use of volumes of non-carbonate raw material components in production of clinker at the enterprises-producers resulted in an increase of CO_2 emission factors in 2013 – 2018. In accordance with data obtained from enterprises-producers starting from 2019 the non-carbonate raw material components use was resumed.

SO_2 emissions from cement production were determined using the method of the Revised Guidelines IPCC [5] based on cement production data, using the default emission factor of 0.3 kg of SO_2 per ton of cement.

4.2.1.3 Uncertainties and time series-consistency

The key factors that determine the uncertainty in cement production are:

- accuracy of results of the chemical analysis of clinker composition, which influences the uncertainty of the emission factor;
- accuracy of analysis of the CKD amount returned to the kiln.
- accuracy of determining the volume of clinker production.

Each of these factors, in accordance with data of the 2006 IPCC Guidelines [1], adds its uncertainty at the level of 2-5%. Uncertainty of the CO_2 emission factor at clinker production is taken to be 5.408% based on analysis of the content of CaO and MgO in clinker, as well as the CKD correction factor uncertainty of 0.859%.

The uncertainty of activity data in accordance with [1] was taken at the level of 1.7%, the overall uncertainty of CO_2 emission estimation at cement production in Ukraine can be set at the level of 5.734%.

4.2.1.4 Category-specific QA/QC procedures

General and detailed QA/QC procedures were applied to calculation of GHG emissions from cement production. Among the detailed quality control procedures, the following were performed:

- comparison of data of cement and clinker production provided by SSSU with data of the enterprises-producers and Ukrainian Association of Enterprises and Organizations of Cement Industry "Ukrcement";
- comparison of the national CO_2 emissions factors with the default emission factors.

4.2.1.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 and SO_2 emissions for 2015 - 2020 was made due to adjustment of the data of cement and clinker production and the data of non-carbonate raw material components use and CaO and MgO content respectively according to the data obtained from enterprises.

Table 4.3 Recalculation of emissions from cement production in 2021.

2.A.1 Cement Production	2015	2016	2017	2018	2019	2020
CO_2						
EF (before recalculating)	0.540584	0.541742	0.54295	0.542851	0.528	0.524
EF (after recalculating)	0.540583	0.541740	0.54294	0.542853	0.530	0.531
Difference.%	-0.00022	-0.00048	-0.0025	0.00042	0.55	1.49
Emissions (before recalculating). kt	3277.52	3622.85	3543.39	3718.73	3947.16	4026.97
Emissions (after recalculating). kt	3277.51	3626.99	3557.11	3716.22	3960.57	4064.9
Difference.%	-0.0002	0.1142	0.3871	-0.0676	0.3398	0.9420
SO_2						
EF (before recalculating)	2.65	2.7296	2.835	2.839	2.882	3.061
Emissions (before recalculating). kt	2.65	2.7335	2.848	2.837	2.874	3.04
Difference.%	0.0	0.143	0.456	-0.084	-0.276	-0.69

4.2.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.2.2 Lime Production (CRF category 2.A.2)

4.2.2.1 Category description

Lime is used in construction, agriculture, and industry for steel, magnesium, copper, soda ash, and sugar production.

According to data of the Ukrainian Association of Lime Industry, the overall structure of lime produced in 2021 is distributed as follows:

- metallurgy - 71%;
- sugar industry - 2%;
- construction - 7%;
- other - 20%;

The largest consumer of lime is the metallurgical industry. The free lime market capacity in 2021 remained - approximately 675 kt of lime (slaked and quicklime), while its share of the total lime market increased to 23.4%.

The reduction of slaked lime production in the period from 2011 to 2021 occurred as a result of changes in the market conditions - the reduced volume of slaked lime consumption as a final product in the construction industry, agriculture, and a reduction in the amount of slaked lime used for water softening in all industries. The inter-annual deviations that occurs in lime production in 1990/1991 by 11.9% are conducted with reduction in production output caused by the collapse of the USSR in 1991, as well as increase in 2011 compared with 2010 by 18.5% are due to recovery in production after global financial and economic crisis in 2008-2009. The inter-annual changes in 2013/2014 by 20.6% are coducted with the economic decrease as a result of the political crisis in Ukraine that began in 2013, which had a significant impact on production in this industry.

The key process in lime production is calcination of limestone ($CaCO_3$) and dolomite ($CaCO_3$*$MgCO_3$) made in kilns. There is slaked lime and quicklime, construction and technology (different in the chemical and mechanical composition), calcite (CaO) and dolomite (CaO*MgO) ones. Quicklime (CaO) is the product of burning and processing of natural calcium carbonates, mainly limestone. Slaked lime $Ca(OH)_2$ is the product of quicklime hydration.

CO_2 is the only GHG emitted in lime production, and the emission volume is directly dependent on the amount and type of produced lime. Table 4.4 shows the basic data on the results of GHG inventory in lime production.

Table 4.4. The basic data on the results of GHG inventory in lime production in 2021.

Category code	2.A.2
Lime production, kt	3088.61
Emissions of CO_2, kt	2353.13

Change in CO_2 emissions compared to the previous year,%	1.39
Change in CO_2 emissions compared to the baseline year,%	-54.06
Emissions, % of the total emissions in the sector	4.71
Emissions, % of the total direct action GHG emissions in the sector	4.03
Key category ("l" - level, "t" - trend)	L
Detail level (Tier)	2
Emission factor, t/t	0.775
Method for determination of the emission factor	T2
Uncertainty of activity data, %	12
Uncertainty of the emission factor, %	16.06
Uncertainty of the emission estimation, %	20.07

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.3, Annex 3.1.1.

4.2.2.2 Methodological issues

CO_2 emissions from lime production were determined in accordance with 2006 IPCC Guidelines [1] (Tier 2 method).

Data of total amounts of lime production in Ukraine were obtained from SSSU [2], with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of the amounts of lime production in 2014 - 2021. The ratio between volumes of production of lime with a high content of calcium and dolomitic lime (85/15) and the content of CaO and MgO in these types of lime was taken by default in accordance with [1]. Humidity of slaked lime calculated based on dry weight was taken as 28%, in accordance with [1].

The total emission factors are not equal to the constant value, as quicklime and slacked lime activity is slightly different, and the ratio of quicklime and slacked lime changes from year to year.

4.2.2.3 Uncertainties and time series-consistency

The uncertainty of CO_2 emission factors in of quicklime and slacked production lime associated with determining of the content of CaO and MgO for all types of lime, as well as the correction for slaked lime according to [1] is taken at the level of 16.06%.

Since data of the total volume of lime production in Ukraine were obtained from SSSU, the uncertainty of the activity data of quicklime and slaked lime production is taken to be at 12%.

The uncertainty of the data of application of the correction factor for lime dust was taken at the level of 0.859%.

The total uncertainty of CO_2 emission from lime production estimation amounted to 20.07%.

4.2.2.4 Category-specific QA/QC procedures

General QA/QC procedures were applied to calculation of GHG emissions from lime production.

- statistical reporting data analysis using alternative sources such as data of the Ukrainian Association of Lime Industry;
- analysis of the time series of activity data and CO_2 emissions.

4.2.2.5 Category-specific recalculations

In this category, no recalculations were made.

4.2.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.2.3 Glass Production (CRF category 2.A.3)

4.2.3.1 Category description

Glass is an inorganic product produced by melting the raw material, forming it to the desired shape, and cooling without crystallization. Silicate glass is the main type of glass produced. The key raw materials for glass production, use of which results in greenhouse gas emissions, are soda ash (Na_2CO_3), limestone, ($CaCO_3$), and dolomite ($CaCO_3$*$MgCO_3$). When assessing GHG emissions from glass production, emissions from use of limestone and dolomite, as well as emissions from use of soda ash in glass production are accounted for.

In the process of glass production, take place CO_2 and NMVOC emissions. Table 4.5 shows the basic data on the results of GHG inventory in glass production.

Table 4.5. The basic data on the results of GHG inventory in glass production in 2021.

Category code	**2.A.3**	
Glass production, kt	1496.4	
Gas	CO_2	NMVOC
Emissions, kt	283.14	6.73
Change in emissions compared to the previous year, %	7.87	10.78
Change in emissions compared to the baseline year, %	51.39	50.39
Emissions, % of the total emissions in the sector	0.57	11.76
Emissions, % of the total direct action GHG emissions in the sector	0.49	
The key category	No	
Detail level (Tier)	3	1
Emission factor, t/t	0.189	0.0045
Method for determination of the emission factor	CS	D
Uncertainty of activity data, %	6.636	
Uncertainty of the emission factor, %	2.31	
Uncertainty of the emission estimation, %	7.027	

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.4, Annex 3.1.1.

4.2.3.2 Methodological issues

The amount of glass produced was taken in accordance with data obtained from SSSU [2] and data obtained from the enterprises-producers with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of the amounts of glass production in 2014 - 2021. The greatest amount of CO_2 emissions in glass production is due to production of flat glass, cans and bottles. Statistics data about window glass production in Ukraine have been confidential since 2004. Therefore, NIR provides information on the total amount of glass produced and the total CO_2 emissions. Volumes of production of other types of glass do not exceed one percent of the total amount of glass.

To estimate emissions in this category, the scientific-research work "Development of methods for estimation and determination of carbon dioxide emissions from limestone and dolomite use" [8] was used, the findings of which were applied to improve accuracy of emission estimates for limestone and dolomite use. A research of activity data and national CO_2 emission factors for glass production was conducted, findings of which made it possible to specify the inventory data by specifying the content of $CaCO_3$ and $MgCO_3$ in limestone and dolomite, which are used in production of flat glass, cans, and bottles, as well as the amount of limestone and dolomite use in glass production for the different years. The soda ash content in furnace charge was obtained from the manufacturing enterprises by each type of glass To avoid double accounting of soda ash use in Ukraine the amounts of soda ash used for glass production were excluded from category 2.A.4.b. Other Process Uses of Carbonates.

NMVOC emissions were defined using the default emission factor of 4.5 kg per tonne of glass recommended by the Revised Guidelines [5].

4.2.3.3 Uncertainties and time series-consistency

The key factors of the uncertainty in glass production are:

- use of the average estimation of the weight of bottles and cans to determine their production in weight units;
- $CaCO_3$ and $MgCO_3$ content in limestone and dolomite;
- specific consumption of the furnace charge.

As a result of the scientific-research work [8], the uncertainty of activity data in glass production is set at 6.636%, and the uncertainty of CO_2 emission factors - at the level of 2.31%. Thus, the uncertainty of CO_2 emission from glass production amounts to 7.027%.

4.2.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions from glass production.

4.2.3.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 emissions for 1990-2020 was made due to adjustment of the data of soda ash content in furnace charge in glass production according to the data obtained from enterprises, as well as CO_2 and NMVOC emissions in 2020 due to correction of the data of glass production according to the data obtained from SSSU [2].

Table 4.6 Recalculation of emissions from glass production in 2021.

2.A.3 Glass Production	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
CO_2								
Emissions (before recalculating), kt	173.23	173.20	160.59	143.06	120.96	114.55	88.35	73.99
Emissions (after recalculating), kt	187.02	187.00	173.66	155.17	131.22	124.31	95.27	80.19
EF (before recalculating)	0.174	0.175	0.176	0.176	0.176	0.175	0.180	0.178
EF (after recalculating)	0.188	0.189	0.190	0.191	0.191	0.190	0.194	0.193
Difference, %	7.96	7.97	8.14	8.47	8.48	8.52	7.83	8.38
2.A.3 Glass Production	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Emissions (before recalculating), kt	71.08	73.23	73.09	196.62	200.10	181.79	183.47	181.89
Emissions (after recalculating), kt	77.04	79.16	79.12	215.29	216.23	197.27	198.28	196.83
EF (before recalculating)	0.179	0.180	0.179	0.187	0.184	0.184	0.184	0.183
EF (after recalculating)	0.194	0.195	0.194	0.204	0.199	0.199	0.198	0.198
Difference, %	8.38	8.10	8.25	9.50	8.06	8.51	8.07	8.21
2.A.3 Glass Production	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Emissions (before recalculating), kt	200.95	224.23	245.80	182.57	218.94	262.30	251.73	249.82
Emissions (after recalculating), kt	217.80	243.50	265.33	196.79	236.00	282.54	271.52	270.42
EF (before recalculating)	0.184	0.184	0.185	0.185	0.184	0.183	0.183	0.183
EF (after recalculating)	0.200	0.200	0.200	0.199	0.198	0.197	0.197	0.198
Difference, %	8.38	8.59	7.95	7.79	7.79	7.71	7.86	8.25
2.A.3 Glass Production	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Emissions (before recalculating), kt	239.17	218.72	228.10	245.43	240.22	258.88	261.11	
Emissions (after recalculating), kt	259.04	237.33	246.90	263.49	259.48	278.14	262.47	
EF (before recalculating)	0.182	0.185	0.185	0.184	0.183	0.184	0.181	
EF (after recalculating)	0.197	0.201	0.200	0.198	0.197	0.197	0.194	
Difference, %	8.31	8.51	8.24	7.36	8.02	7.44	7.38	
NMVOC	**2020**							
Emissions (before recalculating), kt	6.493							
Emissions (after recalculating), kt	6.078							
Difference, %	-6.39							

4.2.3.6 Category-specific planned improvements

In this category, no improvements are planned.

4.2.4 Other Process Uses of Carbonates (CRF category 2.A.4.)

4.2.4.1 Ceramics Production (CRF category 2.A.4.a)

4.2.4.1.1 Category description

In this category, CO_2 emissions from limestone ($CaCO_3$) and dolomite ($CaCO_3$*$MgCO_3$) use in manufacture of ceramics are estimated. Table 4.7 shows the results of the GHG inventory for use of limestone and dolomite.

Table 4.7. Basic data on CO_2 emission inventory results for use of limestone and dolomite in 2021.

Category code	2.A.4.a	
Type of product	Ceramics	
	Limestone	Dolomite
Use, kt	8.92	90.94
Production, kt	2789.72	
Emissions of CO_2, kt	48.92	
Change in CO_2 emissions compared to the previous year, %	-14.53	
Change in CO_2 emissions compared to the baseline year, %	-56.23	
Emissions, % of the total emissions in the sector	0.098	
Emissions, % of the total direct action GHG emissions in the sector	0.084	
The key category	No	
Detail level (Tier)	1	
Emission factor, t/t	0.0175	
Method for determination of the emission factor	D	
Uncertainty of activity data, %	2.4	
Uncertainty of the emission factor, %	5.0	
Uncertainty of the emission estimation, %	5.5	

4.2.4.1.2 Methodological issues

Data of ceramics production and limestone and dolomite use in manufacture of ceramics were taken based on data obtained from the producing companies and the SSSU [2], with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of the amounts of ceramics production in 2014 - 2021. Estimation of CO_2 emissions in production of ceramics was performed in accordance with 2006 IPCC Guidelines [1]. The activity data and estimation results are presented in Annex 3.2.3.

The values of emission factors from limestone and dolomite use in ceramics production were taken by default in accordance with 2006 IPCC Guidelines [1].

4.2.4.1.3 Uncertainties and time series-consistency

The uncertainty of data of limestone and dolomite use in ceramics production was set at 2.4%. The uncertainty of CO_2 emission factors was set at 5%. The uncertainty of emission estimation in limestone and dolomite use in ceramics production amounts to 5.5%.

4.2.4.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions from ceramic production.

4.2.4.1.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 emissions for 2015 - 2020 was made due to adjustment of the data of ceramics production according to the data obtained from enterprises.

Table 4.8 Recalculation of emissions from ceramics production in 2021.

2.A.4.a Ceramics Production	2015	2016	2017	2018	2019	2020
CO_2						
Emissions (before recalculating). kt	69.25	63.95	67.41	66.79	62.4	57.24
Emissions (after recalculating). kt	68.77	63.68	66.93	66.23	61.91	57.72
Difference.%	-0.69	-0.41	-0.71	-0.75	0.77	0.85

4.2.4.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.2.4.2 Other Uses of Soda Ash (CRF category 2.A.4.b)

4.2.4.2.1 Category description

Soda ash (sodium carbonate Na_2CO_3) produces in Ukraine at one plant with using Solvay process (the synthesis process). Soda ash is widely used as a raw material in many industries, mainly in glass production, as well as in chemical industry and detergents production. The interannual deviations in emissions from Soda Ash use are related with changes in soda ash consumption in ukrainian industries, such as Glass production and other industries related with soda ash use. Those changes are associated with sharp changes in amounts of import export and production of soda ash. Table 4.9 shows the results of the GHG inventory in other soda ash use.

Table 4.9. Basic data of CO_2 emission inventory results for other soda ash use in 2021.

Category code	2.A.4.b
Soda ash use, kt	36.93
Emissions of CO_2, kt	15.33
Change in CO_2 emissions compared to the previous year,%	100.46
Change in CO_2 emissions compared to the baseline year,%	-94.64
Emissions, % of the total emissions in the sector	0.03
Emissions, % of the total direct action GHG emissions in the sector	0.026
The key category	No
Detail level (Tier)	1
Emission factor, t/t	0.415
Method for determination of the emission factor	D
Uncertainty of activity data, %	6
Uncertainty of the emission factor, %	7.0
Uncertainty of the emission estimation, %	9.2

4.2.4.2.2 Methodological issues

CO_2 emissions from soda ash use were estimated in accordance with Revised Guidelines IPCC [5] (Tier 1) with default emission factor of CO_2 emissions equal to 0.415 t CO_2 / t soda ash use.

Data of soda ash use was determined on the basis of balance equation with the use of data of soda production, export and import with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of the amounts of soda ash production in 2014 - 2021. Data of soda export and import was obtained from SSSU [22]. Data of soda production was taken from annual report of enterprise-producer. To avoid double accounting of soda ash use in Ukraine the amounts of soda ash used for glass production were included to the category 2.A.3 Glass production.

4.2.4.2.3 Uncertainties and time series-consistency

The uncertainty of data of soda production, exports and imports obtained from statistic data was set at 6%. Taking into account the possibility of volatilization of a certain - amount of CO_2 during soda production with the Solvay process (according to [5], up to 8.4%), uncertainty of the default emission factor of CO_2 emissions was taken at 7%. In this case the uncertainty of CO_2 emission in soda ash use was taken 9.2%.

4.2.4.2.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions from soda ash use.

4.2.4.2.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 emissions for 1990-2020 was made due to adjustment of the data of soda ash content in furnace charge in glass production which are included in category 2.A.3 Glass Production and excluded from this category according to the data obtained from enterprises.

Table 4.10 Recalculation of emissions from Other Uses of Soda Ash in 2021.

2.A.4.b Other Uses of Soda Ash	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
CO_2								
Emissions (before recalculating), kt	298.81	259.43	284.25	184.16	220.86	148.32	60.33	91.97
Emissions (after recalculating), kt	285.84	246.44	271.95	172.77	211.21	139.14	53.85	86.15
Difference, %	-4.34	-5.01	-4.32	-6.19	-4.37	-6.19	-10.73	-6.33
2.A.4.b Other Uses of Soda Ash	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Emissions (before recalculating), kt	79.50	77.01	99.56	47.26	63.53	51.20	91.45	105.11
Emissions (after recalculating), kt	73.91	71.45	93.90	29.60	48.37	36.62	77.53	91.05
Difference, %	-7.04	-7.22	-5.68	-37.36	-23.86	-28.48	-15.22	-13.37
2.A.4.b Other Uses of Soda Ash	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Emissions (before recalculating), kt	87.73	93.94	105.42	58.41	44.82	57.40	40.83	21.76
Emissions (after recalculating), kt	71.88	75.77	87.09	45.08	28.83	38.45	22.28	2.40
Difference, %	-18.07	-19.34	-17.38	-22.83	-35.68	-33.02	-45.43	-88.96
2.A.4.b Other Uses of Soda Ash	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Emissions (before recalculating), kt	14.44	1.63	8.13	32.05	18.34	15.82	1.91	
Emissions (after recalculating), kt	71.87	7.79	19.28	28.87	34.34	20.39	7.65	
Difference, %	397.86	378.75	137.14	-9.91	87.30	28.84	301.00	

4.2.4.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.3 Chemical Industry (CRF category 2.B)

Emissions in this category are related with production of various inorganic and organic chemicals such as Ammonia, Nitric and Adipic acid production, as well as Caprolactam, Carbide, Titanium dioxide and Petrochemical and carbon black production. The main CO_2 emissions occurs in all this categories excluding Nitric, Adipic acid and Caprolactam production where only N_2O occurs as well as CH_4 emission from Carbide and Petrochemical and carbon black production. The precursors and SO_2 emissions occurs in almost all this categories. The key sources emissions are Ammonia and Nitric acid production with CO_2 and N_2O emissions respectively where the emmisions are related the production processes, the correlation of emissions in CO_2-eq and amounts of these products prodution are shown on fig 4.5.

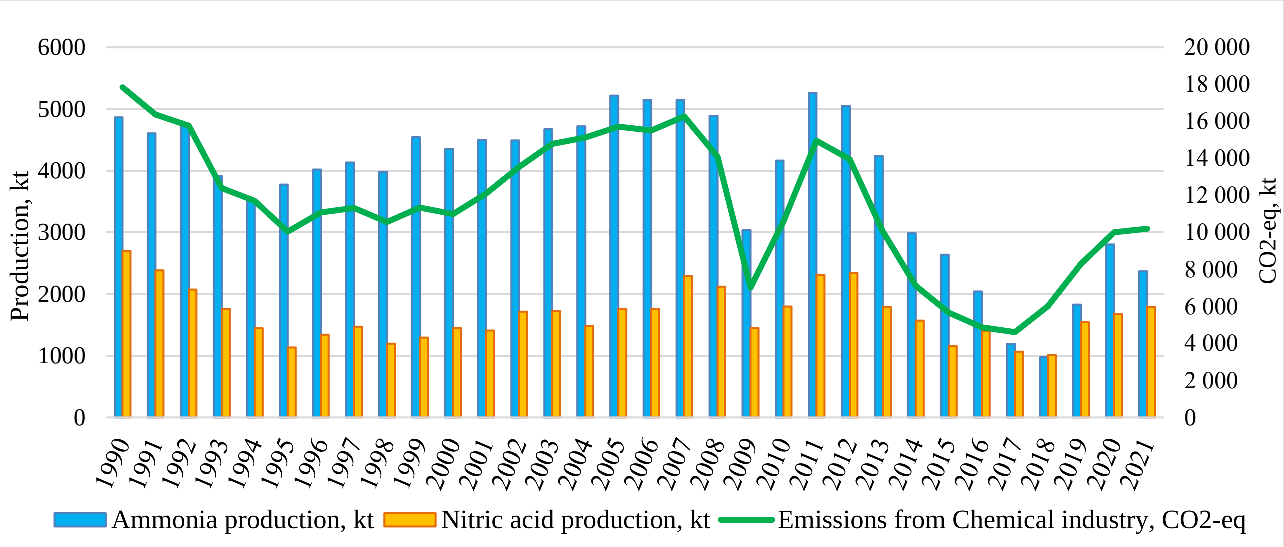


Fig. 4.5. CO_2-eq emissions from Key categories in Chemical industry, kt

Emissions from Adipic acid, Caprolactam, Carbide, Titanium dioxide production, as well as Petrochemical and carbon black production are not shown on the fig 4.5. due to the fact that their contributions to the emissions in Chemical industry category are not as significant as those indicated in graph above and they are not key categories.

The activity data collection, methodological issues as well as QA/QC procedures etc. by the categories included in Chemical industry are shown by each subcategory in relevant chapters.

4.3.1 Ammonia Production (CRF category 2.B.1)

4.3.1.1 Category description

The feedstock for ammonia production in Ukraine is natural gas. The process for ammonia production is based on ammonia synthesis from nitrogen and hydrogen at the temperatures of 380-450ºC and the pressure of 250 atm. using an iron catalyst:

N2 (g.) + 3H2 (g.) = 2NH3 (g.)

Nitrogen is obtained from air. Hydrogen is produced by reduction of water (steam) using methane from natural gas.

Ammonia is used in industry as a raw material for production of nitric acid, nitrogen and complex fertilizers, explosives, dyes, polymers, soda (based on the ammonia method), and other chemical products, as well as a refrigerant.

CO_2 emissions from ammonia production are related to the key categories. To improve accuracy of CO_2 emission estimation, consumption of natural gas as a raw material was taken according to data from six enterprises-producers of ammonia.

SO_2 emissions and precursors: CO, NO_x, NMVOC also occurs in ammonia production. Table 4.11. shows the basic data on the results of GHG inventory in ammonia production.

Table 4.11. The basic data on the results of GHG inventory in ammonia production in 2021.

Category code	2.B.1				
Ammonia production, kt	2369.46				
Consumption of natural gas, M m^3	2616.63				
Gases	CO_2	CO	NO_x	NMVOC	SO_2
Emissions from production, kt	3435.3	0.014	2.37	0.213	0.071
Change in emissions compared to the previous year,%	-13.34	15.57			

Change in emissions compared to the baseline year,%	-64.94	-51.28				
Emissions, % of the total emissions in the sector	6.87	0.04	9.56	0.19	0.12	
Emissions, % of the total direct action GHG emissions in the sector	5.89					
Key category ("l" - level, "t" - trend)	L					
Method for determination of the emission factor	T3	D	D	D	D	
Detail level (Tier)	3	1	1	1	1	
Emission factor at production, t/t	1.45	0.000006	0.001	0.00009	0.00003	
Uncertainty of activity data, %	3					
Uncertainty of the emission factor, %	7					
Uncertainty of data on use of urea,%	5					
Uncertainty of the emission estimation, %	9.11					

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.5, Annex 3.1.1.

4.3.1.2 Methodological issues

Carbon dioxide emissions from ammonia production are calculated in accordance with 2006 IPCC Guidelines (Tier 3 method), according to which consumption of natural gas in calculations is accounted for not only as a raw material component, but also as an energy one to create high-temperature environment. Since ammonia production processes in Ukraine are characterized by use of fuel resource (natural gas) data directly within the production boundaries of the single enterprise, emissions from energy and non-energy use of natural gas in ammonia production – in the subdivision into raw material and energy use of natural gas were accounted in this category and in order to avoid double accounting excluded from category 1.A.2.c (Energy sector).

To account the amount of the excluded CO_2, used for urea (carbamide) production, data of urea production from enterprises and the stoichiometric CO_2 to urea ratio (44/60) were used, in accordance with 2006 IPCC Guidelines [1].

The net calorific value of natural gas was taken in accordance to passports-certificates of physical and chemical properties of natural gas in gas production and gas transportation companies of Ukraine. The determination method and the national value of carbon content in natural gas are presented in Annex P2.5. The value of carbon content in natural gas for 1990-2003 year was taken equal to the value of 2004 in accordance with reccomendations of ARR 2014, para 30 and ARR 2015 para E.10 due to the fact that the passport certificates data for the 1990-2003 year is absent the corresponding information and justification for the assumption is included in Annex A.2.11.1.

The data of amounts of ammonia and urea production as well as natural gas consumption were determinated by using specific values of these amounts for emission calculations in 2021 due to the lack of all data received from manufacturers in 2021.

Estimation of NMVOC, CO, NO_x, and SO_2 emissions from ammonia production was carried out in accordance with 2013 EMEP/EEA Emission Inventory Guidebook [6] using the default emission factors.

4.3.1.3 Uncertainties and time-series consistency

The key factors that determine the uncertainty in ammonia production are:

- The source of obtained activity data of natural gas consumption for ammonia production;
- The total fuel requirement (NCV/ton ammonia);
- The uncertainty of data of CO_2 extracted for further use (urea production);

The uncertainty of data of natural gas consumption for ammonia production obtained from enterprises and used as activity data for estimating CO_2 emissions is taken at the level of 3%. The uncertainty of the emission factor defined as the total fuel requirement (NCV/ton of ammonia) is 7%, as for the average value of specific energy consumption (for modern and older plants). The uncertainty of data on CO_2 extracted for further use (urea production) is taken at the level of 5%. The total uncertainty of CO_2 emission from ammonia production estimation amounted to 9.11%.

4.3.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in ammonia production. In the framework of quality control procedures, the following were performed:

- comparison of the national CO_2 emissions factors with the default IPCC factors.

4.3.1.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 emissions for 1990-2020 was carried out due to the change in the data source of urea production (from the data of SSSU [2] to data received from enterprises), to provide a higher level of data for the Tier 3 for calculation in this category.

Table 4.12 Recalculation of emissions from Ammonia Production in 2021.

2.B.1 Ammonia Production	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
CO_2								
Emissions (before recalculating), kt	9402.92	8831.74	9553.48	7461.46	6833.92	6734.50	7451.15	7353.99
Emissions (after recalculating), kt	9798.96	9218.38	9775.25	7581.56	7059.09	6941.39	7811.61	7625.28
EF (before recalculating)	1.93	1.92	2.02	1.91	1.93	1.78	1.85	1.78
EF (after recalculating)	2.01	2.00	2.07	1.94	1.99	1.84	1.94	1.85
Difference, %	4.21	4.38	2.32	1.61	3.29	3.07	4.84	3.69
2.B.1 Ammonia Production	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Emissions (before recalculating), kt	7221.10	7806.75	7142.48	7461.40	7400.71	7651.86	7542.02	8073.92
Emissions (after recalculating), kt	7451.61	8207.00	7494.39	7789.93	7626.69	7897.63	7896.27	8536.72
EF (before recalculating)	1.81	1.72	1.64	1.66	1.65	1.64	1.60	1.55
EF (after recalculating)	1.87	1.81	1.72	1.73	1.70	1.69	1.67	1.64
Difference, %	3.19	5.13	4.93	4.40	3.05	3.21	4.70	5.73
2.B.1 Ammonia Production	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Emissions (before recalculating), kt	7972.49	7658.52	7493.71	4247.81	6575.74	8166.92	7862.25	6731.26
Emissions (after recalculating), kt	8420.02	8125.78	7939.73	4543.60	6829.83	8585.97	8308.89	6957.84
EF (before recalculating)	1.55	1.49	1.53	1.40	1.58	1.55	1.56	1.59
EF (after recalculating)	1.63	1.58	1.62	1.50	1.64	1.63	1.65	1.64
Difference, %	5.61	6.10	5.95	6.96	3.86	5.13	5.68	3.37
2.B.1 Ammonia Production	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Emissions (before recalculating), kt	4491.11	3800.79	2662.89	1609.17	1275.90	2574.66	4132.88	
Emissions (after recalculating), kt	4542.05	3740.11	2581.25	1575.08	1232.90	2423.91	3964.19	
EF (before recalculating)	1.51	1.44	1.30	1.35	1.31	1.41	1.47	
EF (after recalculating)	1.52	1.42	1.26	1.32	1.26	1.33	1.41	
Difference, %	1.13	-1.60	-3.07	-2.12	-3.37	-5.86	-4.08	

4.3.1.6 Category-pecific planned improvements

In this category, no improvements are planned.

4.3.2 Nitric Acid Production (CRF category 2.B.2)

4.3.2.1 Category description

Nitric acid (HNO_3) is used for production of fertilizers, explosives, in the paint and varnish industry, for etching non-ferrous metals, and so on.

Nitric acid production technology is based on catalytic oxidation of ammonia with the oxygen in the air composition. Thus, the key process steps are:

• contact oxidation of ammonia to obtain nitrogen oxide:

$$4NH_3 + 5O_2 = 4NO + 6H_2O;$$

• oxidation of nitrogen monoxide to dioxide and absorption of the mixture of "nitrous gases" by water:

$$2NO + O_2 = 2NO_2;$$
$$3NO_2 + H_2O = 2HNO_2 + NO$$

The resulting concentration of nitric acid is 55-58%. As a result of the production, N_2O and NO_x are emitted as byproducts.

Currently, nitric acid in Ukraine produces by five companies based on the use of two techniques: on medium pressure units in a pressurized system (7.3 kg/cm^2) and on low-pressure units (3.5 kg/cm^2) under the combined method.

Nitrous oxide forms by catalytic oxidation of ammonia and is an undesirable byproduct of nitric acid production. Provided using an efficient catalyst, usually 92-96% (maximum - 98%) of the fed ammonia converts into nitrogen oxide. The rest of the amount of the ammonia comes into unwanted reactions that lead to formation of nitrous oxide and other substances. These byproducts (including nitrous oxide) are emitted into the atmosphere. Emission calculations were made in view of 100% concentration nitric acid.

Table 4.13 shows the basic data on the results of GHG inventory in nitric acid production.

The inter-annual deviations that occurs in nitric acid production in 2006/2007 by 30.3% are conducted with an increase in the working capacity of enterprises due to an increase in the consumption of feedstock for the production of nitric acid in 2007, as well as the changes in 2010/2011 by 28.6% that occurred as a result by the recovery in production on the enterprises after global fi-nancial and economic crisis in 2008-2009 which impacted on the decrease in production of nitric acid in 2009 compared with 2008 by 31.56%. The inter-annual changes in 2012/2013 by 23.4% are conducted with the economic decrease as a result of the political crisis in Ukraine that began in 2013. The increase in nitric acid production in 2018 compared with 2017 by 9.6% as well as in 2018/2019 by 52.8% is due to gradual growth in the working capacity at the enterprises because of increase in the consumption of feedstock for the production of nitric acid associated with a gradual recovery from the crisis that began in 2013 in accordance with data obtained from enterprises-producers.

In the framework of JI projects in enterprises producing nitric acid in Ukraine were installed secondary catalysts (manufacturer Umicore) for catalytic destruction of nitrous oxide, with the purpose to decomposition of N_2O emissions. At the same time automated emissions monitoring systems (AMS) have been installed.

Table 4.13. The basic data on the results of GHG inventory in nitric acid production in 2021.

Category code	**2.B.2**	
Nitric acid production, kt	1794.99	
Greenhouse gas	N_2O	NOx
Emissions from production, kt	8.08	17.95
Change in emissions compared to the previous year,%	6.88	6.88
Change in emissions compared to the baseline year,%	-54.45	-33.52
Emissions, % of the total emissions in the sector	95.8	72.4
Emissions, % of the total direct action GHG emissions in the sector	4.13	
Key category ("l" - level, "t" - trend)	L	
Detail level (Tier)	2	1
Method for determination of the emission factor	CS/D	D
Emission factor, kg/t	4.5/7.0/5.0	10
Uncertainty of activity data, %	3	
Uncertainty of the emission factor, %	5	
Uncertainty of the emission estimation, %	5.8	

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.6, Annex 3.1.1.

4.3.2.2 Methodological issues

The amount of nitric acid produced in 1990 - 2020 was taken in accordance with data obtained from enterprises. Amount of nitric acid production in 2021 was obtained from SSSU [2] due to the lack of all data received from manufacturers. Nitric acid in Ukraine produces by five companies based on the use of two techniques: on four plants with medium pressure units and on one plant with a low-pressure units. From 1990 till 2008 and in 2010 - 2021 direct measurements of N_2O emissions on entrerprises which produces nitric acid on medium-pressure aggregates UKL-7 was no conducted. In 2009, the company AIRTEC performed a direct test measurements at one enterprise obtaining a value of (4.23 kg/t) as well as on the part of enterprises was inroduced the secondary catalysts for catalytic destruction of nitrous oxide and automated emissions monitoring systems with the purpose to decomposition of N_2O emissions. Therefore, in order to avoid underestimation of emissions from all four enterprises on medium-pressure units according to the recommendation of the Ukrainian Chemists Union(whitch unites all Ukrainian chemical enterprises) as well as the scientific-research work "Development of the method of calculation and determination of GHG emissions in the chemical industry with the construction of particular time-series" [7], in calculations of N_2O emissions for 2009 - 2021 emission factor (4.5 kg/t) was applied. Emissions from UKL-7 for 1990 - 2008 were calculated using N_2O emission factor (7 kg/t), as default, according to 2006 IPCC Guidelines [1]. For enterprise which uses low-pressure units, direct measurements of N_2O emissions was no conducted, therefore, for the emissions calculation the default emission factor (5 kg/t) was used in accordance with 2006 IPCC Guidelines [1].

Estimation of emissions of nitrogen oxides was conducted in accordance with 2013 EMEP/EEA emission inventory guidebook [6] using default emission factors (section 2.9).

4.3.2.3 Uncertainties and time-series consistency

In accordance with the Guidelines [1], the values of the activity data uncertainty are taken at the level of 2%. The values of the uncertainty of emission factors for this category were taken at the level of 5%, in accordance with the recommendations of the 2006 IPCC Guidelines [4]. Thus, the total uncertainty of the estimates of nitrous oxide emissions from nitric acid production amounts to 5.4%.

4.3.2.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in production of nitric acid.

4.3.2.5 Category-specific recalculations

In this category, no recalculations were made.

4.3.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.3.3 Adipic Acid Production (CRF category 2.B.3)

4.3.3.1 Category description

Adipic acid ($HOOC(CH_2)4COON$) is a dicarboxylic acid, which is produced by oxidation of a mixture of cyclohexanone and cyclohexanol with nitric acid in the presence of a vanadium catalyst. The oxidation process with nitric acid releases nitrous oxide as an undesirable byproduct (N_2O).

Adipic acid production is also accompanied by emissions of NMVOC, CO, and NO_x.

In Ukraine, the technique of thermal destruction of N_2O is used at adipic acid production. The unit for thermal destruction of N_2O was developed by Severodonetsk branch of the "Institute of Nitric Industry" together with BASF, which was the supplier of the technology and equipment for adipic acid production.

The reduction in the amount of production of adipic acid and, therefore, of emissions in 2009 was due to the economic crisis and the general decline in industrial production in that period.

According to the activity data provided by producing enterprises and by the State Enterprise "Cherkasky NIITEKHIM", adipic acid has not been produced since 2013, so the emissions in this category were not estimated. Data of adipic acid production in Ukraine for the whole time series are shown in the table A3.1.1.7 in Annex 3 and the CRF tables.

4.3.3.2 Methodological issues

Data of adipic acid production were provided by the enterprises-producers. For estimation of N_2O emissions from adipic acid production, 2006 IPCC Guidelines [1], using Tier 2 method with default emission factors were used. Estimation of emissions of NMVOC, CO, and NO_x was conducted in accordance with 2013 EMEP/EEA emission inventory guidebook [6] using default emission factors.

4.3.3.3 Uncertainties and time-series consistency

According to the activity data provided by producing enterprises and by the State Enterprise "Cherkasky NIITEKHIM", adipic acid has not been produced since 2013, so the uncertainties in this category were not calculated.

4.3.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in adipic acid production.

4.3.3.5 Category-specific recalculations

In this category, no recalculations were made.

4.3.3.6 Category-specific planned improvements

In this category, no improvements are planned.

4.3.4 Caprolactam, Glyoxal, and Glyoxylic Acid Production (CRF category 2.B.4)

4.3.4.1 Category description

This section is dedicated to production of three chemicals - caprolactam, glyoxal, and glyoxylic acid, which are potentially important sources of nitrous oxide (N_2O) emissions in the countries where they are produced.

In Ukraine, glyoxal and glyoxylic acid are not produced. Almost all of the annual production of caprolactam ($C_6H_{11}NO$) is consumed as the monomer for nylon-6 fibres and plastics (Kirk-Othmer, 1999; p.310), with a substantial proportion of the fibre used in carpet manufacturing.

Mostly, caprolactam is produced by the Raschig method, as a result of Beckmann rearrangement (conversion of a ketone oxime into an amide, usually using sulphuric acid as a catalyst) by the addition of hydroxylamine sulphate to cyclohexanone. Hydroxylamine sulphate is produced from ammonium nitrate and sulphur dioxide. Ammonia gas and air are fed to a converter where ammonia is converted to hydroxylamine disulphonate by contacting it with ammonium carbonate and sulphur dioxide in series. Ammonium carbonate is produced by dissolving ammonia and carbon dioxide in water, and sulphur dioxide by burning sulphur. The disulphonate is hydrolysed to hydroxylamine sulphate and ammonium sulphate. The addition of hydroxylamine sulphate to cyclohexanone produces cyclohexanone oxime which is converted to caprolactam by the Beckmann rearrangement.

4.3.4.2 Methodological issues

According to the activity data provided by enterprises-producers and by the State Enterprise "Cherkasky NIITEKHIM", caprolactam has not been produced since 2014, so the emissions in this category were not estimated. For estimation of N_2O emissions from caprolactam production for 1990 - 2013, 2006 IPCC Guidelines [1], using Tier 1 method with default emission factor was used.

4.3.4.3 Uncertainties and time-series consistency

According to the activity data provided by producing enterprises and by the State Enterprise "Cherkasky NIITEKHIM", caprolactam has not been produced since 2014, so the uncertainties in this category were not calculated.

4.3.4.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in caprolactam production.

4.3.4.5 Category-specific recalculations

In this category, no recalculations were made.

4.3.4.6 Category-specific planned improvements

In this category, no improvements are planned.

4.3.5 Carbide Production and Use (CRF category 2.B.5)

4.3.5.1 Category description

Calcium carbide CaC_2 is obtained by calcination of a mixture of limestone with coal dust in electric furnaces and subsequent recovery of lime. Silicon carbide is produced in electric furnaces at 2000 - 2200˚C from the mixture of quartz sand (51-55%), coke (35-40%) with the addition of sodium chloride (1-5%) and sawdust (5-10%). In this category, CO_2 emissions occurs from limestone in production of CaC_2 and SiC, as well as in the lime recovery process and calcium carbide utilization. In production of silicon carbide, also occurs CH_4 emissions. The data about silicon and calcium carbide production in Ukraine is confidential. Table 4.14 shows data on CO_2 emissions from production and use of calcium carbide and CH_4 emissions from silicon carbide production.

Table 4.14. The basic data on the results of GHG inventory in carbide production and use in 2021.

Category code	**2.B.5**	
Carbide Production and Use, kt	C	
Greenhouse gas	CO_2	CH_4
Emissions, kt	48.06	0.21
Change in emissions compared to the previous year,%	148.78	148.78
Change in emissions compared to the baseline year,%	-60.63	40.93
Emissions, % of the total emissions in the sector	0.096	0.13

Emissions, % of the total direct action GHG emissions in the sector	0.082	0.009
The key category	No	
Detail level (Tier)	1	1
Method for determination of the emission factor	D	D
Uncertainty of activity data, %	5	5
Uncertainty of the emission factor, %	10	10
Uncertainty of the emission estimation, %	11.180	

4.3.5.2 Methodological issues

The data of calcium and silicon carbide production were provided by the enterprises-producers and SSSU [2]. For calculation of emission factors of CO_2 and CH_4 for silicon carbide production, as well as in calcium carbide using, the default factors were used [1].

4.3.5.3 Uncertainties and time-series consistency

The uncertainty of the default CO_2, CH_4 emission factors is taken at the level of 10%. The uncertainty of the data of calcium and silicon carbide production provided by the enterprises-producers is taken at the level of 5%.

Thus, the total uncertainty of CO_2 and CH_4 emissions in calcium carbide and silicon carbide production amounts to 11.180%.

4.3.5.4 Category-specific QA/QC pro cedures

General QA/QC procedures were applied for estimation of GHG emissions in production and use of calcium carbide.

4.3.5.5 Category-specific recalculations

In this category, no recalculations were made.

4.3.5.6 Category-specific planned improvements

In this category, no improvements are planned.

4.3.6 Titanium Dioxide Production (CRF category 2.B.6)

4.3.6.1 Category description

Titanium dioxide (TiO_2) is one of the most commonly used white pigments. The main use is in paint manufacture followed by paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink, and other miscellaneous uses.

There are three processes that are used in the production of TiO_2 that lead to process greenhouse gas emissions: titanium slag production in electric furnaces, synthetic rutile production using the Becher process, and rutile TiO_2 production via the chloride route. Titanium slag used for production of anatase TiO_2 is produced from electric furnace smelting of ilmenite. Where titanium slag is used the acid reduction step is not required as the electric furnace smelting reduces the ferric iron contained as an impurity in ilmenite. Rutile TiO_2 may be produced by further processing of the anatase TiO_2..

Process emissions arise from the reductant used in the process. Production of synthetic rutile can give rise to CO_2 emissions where the Becher process is used. This process reduces the iron oxide in ilmenite to metallic iron and then reoxidises it to iron oxide, and in the process separates out the titanium dioxide as synthetic rutile of about 91 to 93 percent purity (Chemlink, 1997). Black coal is used as the reductant and the CO_2 emissions arising should be treated as industrial process emissions. The main route for the production of rutile TiO_2 is the chloride route. Rutile TiO_2 is produced through the carbothermal chlorination of rutile ore or synthetic rutile to produce titanium tetrachloride ($TiCl_4$) and oxidation of the $TiCl_4$ vapours to TiO_2. Table 4.15 shows the basic data on the results of GHG inventory in titanium dioxide production.

Table 4.15. The basic data on the results of GHG inventory in dioxide titanium production in 2021.

Category code	2.B.6
Titanium Dioxide Production, kt	123.28
Emissions of CO_2, kt	165.2
Change in CO_2 emissions compared to the previous year,%	3.19
Change in CO_2 emissions compared to the baseline year,%	-27.00
Emissions, % of the total emissions in the sector	0.33
Emissions, % of the total direct action GHG emissions in the sector	0.28
The key category	No
Detail level (Tier)	1
Method for determination of the emission factor	D
Uncertainty of activity data, %	6
Uncertainty of the emission factor, %	15
Uncertainty of the emission estimation, %	16.155

4.3.6.2 Methodological issues

Data of titanium dioxide production was obtained from the enterprises-producers with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of the amounts of titanium dioxide production in 2017 – 2021. For estimation of CO_2 emissions from titanium dioxide production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.3.6.3 Uncertainties and time-series consistency

The uncertainty of production data is estimated at 6%. The uncertainty of the default CO_2 emission factors is set at 15%. Thus, the uncertainty of CO_2 emission from titanium dioxide production in Ukraine amounts to 15.81%.

4.3.6.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in production of titanium.

4.3.6.5 Category-specific recalculations

In this category, no recalculations were made.

4.3.6.6 Category-specific planned improvements

In this category, no improvements are planned.

4.3.7 Soda Ash Production (CRF category 2.B.7)

4.3.7.1 Category description

In Ukraine, soda ash production takes place at one plant with Solvay process (the synthesis process) which involves capturing carbon dioxide released during the occurrence of side reactions(such as calcining limestone with metallurgical grade coke or anthracite) and return it to the process, assessment of CO_2 emissions from the production process does not performes, which does not disagree with the requirements of the IPCC, according to research work "Development of the method of calculation and determination of GHG emissions in the chemical industry with the construction of particular time-series" [7].

4.3.8. Petrochemical and Carbon Black Production (CRF category 2.B.8)

4.3.8.1 Category description

In this category, estimation of carbon dioxide and methane emissions in carbon black, ethylene and methanol production, as well as precursors (CO, NO_x, NMVOCs) and SO_2 in manufacture of chemical products: carbon black, ethylene, vinyl chloride monomer, methanol, polystyrene, propylene, polypropylene, polyethylene, sulfuric acid, and phthalic anhydride was made.

According to the data obtained from enterprises-producers carbon black in Ukraine produces with using (default) furnace black with thermal treatment process and it uses as a reinforcing component in production of rubbers and other plastic masses. In production of carbon black occurs emissions of CO_2, CH_4, and all precursors GHGs - NO_x, CO, SO_2 and NMVOCs. Since 2007, statistics of carbon black production in Ukraine is confidential. Data of carbon black production in 2021 were provided by the enterprises-producers.

Ethylene (C_2H_4) is a product of oil and natural gas refining. It used as a raw material in production of polyethylene, ethyl alcohol, and polyvinyl chloride. In ethylene production occurs CO_2, CH_4, and NMVOC emissions. Since 2003, statistics of ethylene production in Ukraine is confidential. According to the data obtained from only one plant producer of ethylene in Ukraine there was no production in 2009 and since 2013 till 2016, in 2017 - 2021 production resumed. The lack of production in 2009 is explained by the global financial and economic crisis in 2008 - 2009 and the economic decrease as a result of the political crisis in Ukraine that began in 2013, which has had a significant impact on production in major industries.

According to the data obtained from enterprises-producers methanol (methyl alcohol) CH_3OH was produced with using (default) conventional steam reforming without primary reformer process. It is used for denaturing ethyl alcohol, formaldehyde production and as a solvent and reagent in organic synthesis. In production of methanol occurs CO_2 and CH_4 emissions. Since 2006, statistics of methanol production in Ukraine is confidential. Data of methanol production in 2021 was provided by the enterprise-producer.

According to the data obtained from enterprise-producer VCM (vinyl chloride monomer) in Ukraine produces with using (default) balanced process for VCM production with integrated VCM production plant which is used for further production of polyvinyl chloride. In vinyl chloride monomer production occurs CO_2, CH_4, and NMVOC emissions. Data about vinyl chloride monomer production in Ukraine is confidential. According to the data obtained from only one plant producer of vinyl chloride monomer in Ukraine there was no production in 2009 and since 2014 till 2016, in 2017 - 2021 production resumed. The lack of production in 2009 is explained by the global financial and economic crisis in 2008 - 2009 and the economic decrease as a result of the political crisis in Ukraine that began in 2013, which has had a significant impact on production in major industries.

Polystyrene is obtained by catalytic dehydrogenation of ethylbenzene in the presence of catalysts and it is used in plastics and synthetic rubbers production. In production of polystyrene occurs only NMVOC emissions. Since 2008, statistics of polystyrene production in Ukraine is confidential. Data of polystyrene production in 2021 were provided by enterprises-producers.

Propylene (C_3H_6) is found in cracking, petroleum pyrolysis gases, in coke gases. It is obtained by extraction from oil refinery gases, as well as through catalytic dehydrogenation of propane, light gasolines. It is used as a raw material in the petrochemical industry, in plastics, rubber, motor fuel and solvents production. In propylene production only NMVOC emissions take place. Since 2003, statistics of propylene production in Ukraine is confidential. Since 2013 till 2016, propylene has not been produced in Ukraine, due to lack of raw materials for production caused by by the economic decrease as a result of the political crisis in Ukraine that began in 2013, which was confirmed with data provided by the SE "Cherkasky NIITEKHIM. According to the data provided by enterprise-producer and SSSU [2] propylene production in 2017 - 2021 was resumed.

Polypropylene is obtained by polymerizing propylene in the presence of metal catalysts. It is used for films (especially packaging ones), containers, pipes, technical equipment parts, household items, electrical insulation and non-woven materials production. In production of polypropylene, only NMVOC emissions take place. Since 2005, statistics of polypropylene production in Ukraine is confidential. Since 2013 till 2016, polypropylene has not been produced in Ukraine, due to lack of raw materials for production caused by by the economic decrease as a result of the political crisis in Ukraine that began in 2013 which was confirmed with data provided by the SE "Cherkasky NIITEKHIM", in 2017 - 2021 polypropylene production resumed, according to data obtained from SSSU [2].

Polyethylene is produced by polymerization of ethylene at high temperature and pressure in the presence of catalysts. It is used primarily as a packaging material. In polyethylene production only NMVOC emissions take place. Since 2005, statistics of polyethylene production in Ukraine is confidential information. Data of polyethylene production in 2021 was received from the enterprise-producer.

Sulfuric acid (H_2SO_4) is produced by catalytic oxidation of SO_2. In Ukraine, sulfuric acid produces by chemical, coke enterprises and metallurgy ones. It is used in mineral fertilizers, various salts and acids production, in organic synthesis, in petroleum, metal, textile, and leather industries. In production of sulfuric acid only SO_2 emissions take place. To assess GHG emissions of sulfuric acid production, data provided by the SSSU [2] was used.

Phthalic anhydride is a raw material for a wide range of plasticizers, water-soluble polyester resins production, the raw material for which is orthoxylene or naphthalene. In 2010, phthalic anhydride production from naphthalene use was stopped in Ukraine. In 2011, phthalic anhydride was produced only from orthoxylene. In production of phthalic anhydride only NMVOC emissions take place. Since 2006, statistics of phthalic anhydride production in Ukraine is confidential. Since 2013, phthalic anhydride has not been produced in Ukraine, which was confirmed with data provided by the SE "Cherkasky NIITEKHIM".

Table 4.16 shows the basic data on the results of GHG inventory in this category.

Table 4.16. The basic data on the results of GHG inventory in the category Petrochemical and Carbon Black Production in 2021

Category code	**2.B.8**					
Gases	CO_2	CH_4	NO_x	CO	NMVOC	SO_2
Emissions in production, kt	784.18	134.22	1.44	2.88	1.31	9.18
Change in emissions compared to the previous year,%	16.05	14.10	13.64	13.64	17.90	14.21
Change in emissions compared to the baseline year,%	-60.04	4653.2	-63.15	-63.15	91.67	-82.02
Emissions, % of the total emissions in the sector	1.57	86.1	5.81	7.9	1.18	16.03
Emissions, % of the total direct action GHG emissions	1.34	5.75				
in the sector						
Key category ("l" - level, "t" - trend)	No	L/T				
Detail level (Tier)	1	1	1	1	1	1
Method for determination of the emission factor	D	D	D	D	D	D
The uncertainty of the CO_2 emission estimation, %	3.39					
The uncertainty of the CH_4 emission estimation, %	10					
The total uncertainty for the category,%	10.56					

GHG emission data throughout the entire time series in this category are shown in Table A3.1.1.8, Annex 3.1.1.

4.3.8.2 Methodological issues

For calculation of CO_2 and CH_4 emissions from the petrochemical industry 2006 IPCC Guidelines [1] with the default emission factors was used. Indirect GHG emission estimation in the category was conducted in accordance with 2013 EMEP/EEA Emission Inventory Guidebook [6] (Tier 2 method) and the scientific-research work "Development of methods for calculation and determination of GHG emissions in the chemical industry with the construction of particular time series"[7] performed by State Enterprise "Ukrainian Research Institute of Transport Medicine" of the Ministry of Health of Ukraine, using the method of calculation of Cherkassy NIITEKHIM. The activity data were provided by the enterprises-producers, SE "Cherkassy NIITEKHIM", and SSSU [2], with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of the amounts of petrochemical products production in 2014.

4.3.8.3 Uncertainties and time-series consistency

Out of GHGs, in this category carbon dioxide and methane emissions from carbon black, ethylene, and methanol production are accounted. The uncertainty of CO_2 emission estimation is 3.394%, that of CH_4 - 10%. The total uncertainty of the subcategory is 10.56%.

4.3.8.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in chemical production.

4.3.8.5 Category-specific recalculations

In this category, no recalculations were made.

4.3.8.6 Planned improvements

In this category, no improvements are planned.

4.3.9 Fluorochemical Production (CRF category 2.B.9)

In accordance with the scientific-research works: by the Ukrainian Research Institute of Medicine and Transport of the Ministry of Health of Ukraine "Development of methods of estimation and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride"[7] and by Cherkasy NIITEKHIM" - "Development of methods of estimation and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride" [13] there is no fluorochemical production in Ukraine, therefore emissions in this category are not estimated.

4.4 Metal Industry (CRF category 2.C)

Emissions in this category are the result from the production of metals such as Iron, Steel, Sinter, Pellets, Ferroalloys, Aluminium, Lead and Zinc production, as well as limestone and dolomite use. The main CO_2 emissions occurs in all this categories as well as CH_4 emission from Iron, Sinter and Ferroalloys production and PFCs emissions from Aluminium production. The precursors and SO_2 emissions occurs only from Iron and Steel production. The key sources emissions are Iron, Steel and Ferroalloys production with CO_2 and CH_4 emissions respectively where the emmisions are related with the production processes, the correlation of emissions in CO_2-eq and amounts of these products prodution are shown on fig 4.6.

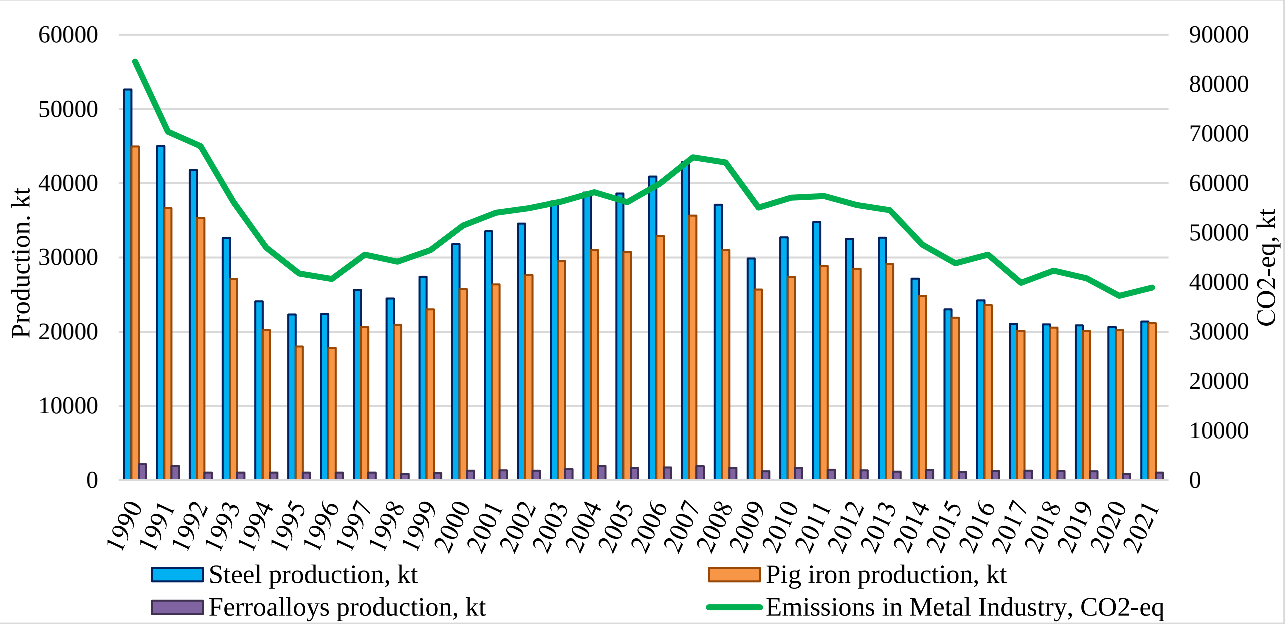


Fig. 4.6. CO_2-eq emissions from Key categories in Metal industry, kt

Emissions from Sinter, Pellets, Aluminium, Lead and Zinc production are not shown on the fig 4.6. due to the fact that their contributions to the emissions in Metal industry category are not as significant as those indicated in graph above and they are not key categories.

The activity data collection, methodological issues as well as QA/QC procedures etc. by the categories included in Metal industry are shown by each subcategory in relevant chapters.

4.4.1 Iron and Steel Production (CRF category 2.C.1)

4.4.1.1 Category description

Category Iron and Steel production is the key category and the largest source of GHG emissions in the sector.

The greatest emissions occurs from pig iron production, which is produced by reduction of iron ore in blast furnace process. Carbon contained in coke is used both as fuel, and as a reducing agent. In accordance with 2006 IPCC Guidelines [1], emissions from energy and non-energy use of coke in the blast furnace process for iron production were accounted in the sector "Industrial Processes and Product Use". Table 4.17 shows the basic data on the results of GHG inventory in iron and steel production.

Table 4.17 Basic data on the results of GHG inventory in iron and steel production in 2021

Category code	**2.C.1**							
Iron production, kt	21165.00							
Steel production, kt	21366.00							
Sinter production, kt	32917.00							
Pellet production, kt	20133.92							
Consumption of natural gas, M m3	2.42							
Limestone use, kt	7726.4							
Dolomite use, kt	20.0							
Gases	All GHGs	CO_2	CH_4 (pig iron)	CH_4 (sinter)	NO_x	CO	NMVOC	SO_2
Emissions, kt	37299.42	36765.61	19.05	2.30	1.93	27.57	7.08	42.4
Change in emissions compared to the previous year,%	3.88	3.88	4.58	3.17	5.23	4.58	3.73	4.59
Change in emissions compared to the baseline year,%	-53.84	-53.86	-52.89	-45.97	-52.92	-52.85	-49.51	-52.92
Emissions, % of the total emissions in the sector		75.09	12.22	1.48	7.79	75.64	6.34	74.06

Emissions, % of the total direct action GHG emissions in the sector	63.91	63.00	0.82	0.02				
Key category ("l" - level, "t" - trend)		L/T	No	No				
Detail level (Tier)		3	1	1	1	1	1	1
Emission factor for pig iron, t/t		1.59	0.0009	0.00007				
Emission factor for steel, t/t		0.133						
Emission factor for limestone, kg/t		0.4337						
Emission factor for dolomite, kg/t		0.4645						
Method for determination of the emission factor		CS	D	D	D	D	D	D
Uncertainty of activity data, %		5.06	5					
Uncertainty of the emission factor, %		4.58	20					
Uncertainty of the emission estimation, %		6.82	20.6					

The decrease in emissions from iron and steel production in 2021 compared to the baseline year was due to reduction in the volume of their production after the collapse of the USSR. The growth of emissions in 2021 compared to 2020 - to a increase in the iron and steel production, as well as in coke consumption for iron production and, as a result, the of growth pulverized coal consumption after its application at metallurgical enterprises of after the 2008/2009 crisis. Activity data, emission factors, and GHG emissions for the entire time series in this category are listed in Tables A3.1.1.9, annex A3.1.1.10.

4.4.1.2 Methodological issues

4.4.1.2.1 Iron Production

In GHG inventory, Tier 3 method was used in this category in accordance with 2006 IPCC Guidelines [1]. The activity data of the amount of iron produced were obtained from SSSU [2]. The amounts of coke, coal, and natural gas consumption for iron production were taken with using extrapolation method, based on data of the growth of pig iron production in Ukraine in 2020-2021 obtained from Association "Metallurgprom", in accordance with 2006 IPCC Guidelines, Chapter 5.3 Resolving data gaps [1].

The carbon content in iron and coke was taken in accordance with the data obtained from the enterprises-producers. In the calculations, the national value of carbon content in natural gas was used, the determination method and the value of which are presented in Annex 2.5. The net calorific value of natural gas was taken in accordance to passports, certificates of physical and chemical properties of natural gas in gas production and gas transportation companies of Ukraine. The carbon content of coal was taken on the basis of the values of net calorific value of coal and sulfur content in coal with the corresponding net calorific value in accordance with data obtained from the enterprises-producers. The ore used for iron production in Ukraine does not contains carbon. In the estimation assessment, the scientific-research works were used: "Development of methods of estimation and prediction of GHG emissions at the metallurgical enterprises of Ukraine" [10] and "Development of the method of estimation and determination of carbon dioxide emissions in iron and steel production" [13]. Use of these scientific-research works made it possible to specify all the details of production components at each Ukrainian enterprise. Since iron production processes in Ukraine are characterized by use of fuel resource (coke) directly within the production boundaries of the single enterprise, emissions from energy and non-energy use of coke in iron production – in subdivision into raw material and energy use of the coke were accounted in this category and in order to avoid double accounting excluded from category 1.A.2.a (Energy sector).

Annex 3.1.3 presents the method of determining the emission factor when using coal and coke, and Annex 3.1.4 - the carbon balance in the blast furnace process developed as a result of the research [10] conducted for 2021.

The methane emission factor in iron production, in accordance with [3], was assumed to be 0.9 kg per ton of pig iron. The emission factors for precursors in this category were taken as equal to the default values in 2013 EMEP/EEA Emission Inventory Guidebook [6].

4.4.1.2.2 Steel Production

Emissions from steel production were determined in accordance with the Guidelines [1] for each type of steel production (in basic oxygen furnaces (BOF), electric arc furnaces (EAF), and open hearth furnaces (OHF)), taking into account the specific consumption of iron and carbon content in each type of steel (Tier 3 method) in accordance with data obtained from enterprises-producers and Association "Metallurgprom". For 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of steel production and iron, scrap metal and carbon electrodes consumption. As a result of conducted scientific-research work [10], it was found out that in the steel production, it is also necessary to account the carbon that enters to steel making furnaces with scrap metal. Therefore, the calculation was extended with the component that takes into account the carbon entering the furnace with scrap metal. The amounts of iron, and scrap metal consumption for steel (in basic oxygen furnaces (BOF) and electric arc furnaces (EAF) production were determinated by using specific values of these amounts for emission calculations in 2021 due to the lack of all data received from manufacturers in 2021.

As a result of conducted scientific-research work was identified the national emissions factors in steel production, which are within the ranges:

- (in 2021 - 138 kg/t) - for steel produced in the OHF;
- (in 2021 - 141 kg/t) - for steel produced in the BOF;
- (in 2021 – 8.9 kg/t) - for steel produced in the EAF;
- (in 2021 - 133 kg/t) - the average for all types of steel.

The emission factors for precursors in this category were taken as equal to the default values in 2013 EMEP/EEA Emission Inventory Guidebook [6].

4.4.1.2.3 Sinter and Pellet Production

In statistical reporting Form 4-MTP[20], coke consumption in sinter and pellet production is shown along with coke consumption for iron production. Therefore, emissions from sinter and pellet production are accounted together with the emissions from iron production.

Estimation of methane emissions from sinter production was carried out in accordance with the recommendations [1] using the default factor. According to 2013 EMEP/CORINAIR Emission Inventory Guidebook [6], assessment of NMVOC emissions from sinter and pellets production with the default factors was conducted, the emissions were combined with the total emissions of precursors in the category.

4.4.1.2.4 Limestone and Dolomite Use

This category accounts CO_2 emissions from limestone and dolomite use as fluxes in sinter, pellets, iron, and steel production, which were combined with the total in the category. The amount of limestone, dolomite limestone, and dolomite used in metallurgy was taken on the basis of data obtained from the iron, steel, sinter and pellets enterprises-producers.

In the estimations in the category, the scientific-research works were used: "Development of methods of estimation and prediction of greenhouse gas emissions at the metallurgical enterprises of Ukraine" [10] and "Development of the method of estimation and determination of carbon dioxide emissions in limestone and dolomite use" [8] developed by SE "State Ecology Academy of Postgraduate Education and Management" and SE "UkrRTC "Energostal". The obtained results of these scientific-research works made possible to specify the details of all components used as fluxes in metallurgical production at each Ukrainian enterprise, as well as data of the content of $CaCO_3$ and $MgCO_3$ in limestone, dolomite limestone, and dolomite, on the basis of which the emission factors and CO_2 emissions were identified. The activity data and estimation results are presented in Annex 3.1.2.

The value of the total CO_2 emission factor in limestone and dolomite use in 2021 increased 0.4338 t/t.

4.4.1.3 Uncertainties and time-series consistency

The key factors that impacted on the value of the uncertainty of the activity data for iron and steel production are:

- accuracy of measurements of the mass/volume of reducers and manufactured products;
- uncertainties caused by the recalculation of masses;
- uncertainties caused by generalization of activity data.

The key factors that impacted on the value of the uncertainty of emission factors for iron and steel production are:

- uncertainty of the data of carbon content in raw materials, reducing agents, and manufactured products;
- accuracy of determining the net calorific value of the fuel used as a reducing agent;
- uncertainty caused by the representative nature of the sample for measurement;
- uncertainties caused by generalization of data on physical and chemical properties of reducing agents and the products.

The findings of study [10] made possible to estimate the uncertainty of the activity data obtained for iron production at the level of 2.19% and of steel - at the level of 0.84%.

The uncertainty of emission factors for iron and steel production is estimated at the level of, respectively, 2.75% and 1.75%.

Taking into account emissions from iron and steel production, the total uncertainty of the activity data for production of iron and steel is 5.06%, the uncertainty of emission factors - 4.58%, and the uncertainty of emission volumes - 6.82%.

The uncertainty of the methane emission factor in iron production is taken to be 20%. Given the uncertainty of the activity data (5%), the total uncertainty of the methane emission estimation in iron production amounted to 20.6%.

4.4.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied to estimation of carbon dioxide emissions from iron and steel production, including:

- analysis of the time-series of the activity data (iron and steel production volumes) and emission factors;
- comparison of data of iron production obtained from SSSU [2] with those provided by Association "Metallurgprom";
- carbon balance analysis in the blast furnace process (Annex 3.1.4);
- analysis of the coke balance in Ukraine (Annex 2.8).

4.4.1.5 Category-specific recalculations

In 2021, recalculation of CO_2 and NMVOC emissions for 2019 – 2020 was made due to correction of the pellets production according to the data obtained from enterprises-producers.

Table 4.18 Recalculation of emissions from iron and steel production in 2021.

2.C.1 Iron and Steel Production	**2019**	**2020**
CO_2		
Emissions (before recalculating), kt	38909.44	35903.27
Emissions (after recalculating), kt	38 910.01	35 904.81
Difference, %	0.001	0.004
NMVOC		
Emissions (before recalculating), kt	6.7071	6.820
Emissions (after recalculating), kt	6.7077	6.822
Difference, %	0.009	0.024

4.4.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.4.2 Ferroalloys Production (CRF category 2.C.2)

4.4.2.1 Category description

Ferroalloys are semi-finished metal production products - iron alloys with silicon, manganese, chromium, and other elements used in steel production (for deoxidation and alloying of steel, binding of harmful impurities, ensuring the desired metal structure and properties). Ferroalloys differ in content of the key elements, carbon, and impurities. Ferroalloys are obtained through pyrometallurgical methods of basic metal and iron oxides reduction. The most common method of producing ferroalloys is the electrothermal one. By the type of the reducing agent, it is subdivided into carbon-reduction one, producing carbon ferroalloys (8.5% C) and all silicon alloys, and metallo-thermal one (conventionally including the silicothermic one), which produces alloys with low carbon content (0.01-2.5%C). Ferroalloy smelting is carried out in three-phase electric ore reduction and refined furnaces of the open and closed types.

The alloys production technology provides for a continuous process with periodic releases of smelting products. Solid pure coke and coal carbon is used as a reducing agent in accordance with the direct reduction technology. Thus the reduction product is carbon mono-oxide and dioxide (CO and CO_2). There are only ferrosilicon, ferromanganese, ferrosilicomanganese (silicon manganese) and ferronickel production in Ukraine. Table 4.19 shows the basic data of GHG inventory for carbon dioxide and methane in production of ferroalloys in Ukraine.

Table 4.19. The basic data on the results of GHG inventory in ferroalloys production in 2021.

Category code	**2.C.2**	
Ferroalloys Production, kt	1017.8	
Limestone use, kt	14.12	
Gas	CO_2	CH_4
Emissions, kt	1606.13	0.092
Change in emissions compared to the previous year,%	-5.61	53.43
Change in emissions compared to the baseline year,%	-47.68	-84.81
Emissions, % of the total emissions in the sector	3.21	0.059
Emissions, % of the total direct action GHG emissions in the sector	2.75	0.0039
Key category ("l" - level, "t" - trend)	L	
The level of detail for ferroalloys (Tier)	3	1
Emission factor, t/t	1.58	0.001
Method for determination of the emission factor for ferroalloys	CS	D
Uncertainty of activity data, %	10.6	5.25
Uncertainty of the emission factor, %	5	31.25
Uncertainty of the emission estimation, %	11.7	31.68

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table 3.1.1.11, Annex 3.1.1.

4.4.2.2 Methodological issues

As the activity data in the inventory of emissions in this category, statistical data of ferroalloys production provided by SSSU [2] and the five largest Ukrainian ferroalloy enterprises were used, with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of amounts of ferroalloys production for 2014.

The national emission factors are determined on the basis of the data of ferroalloys production, the weight of the used ore, concentrate, sinter, reducing agents, slag-forming materials and waste, as the carbon content in reducing agents, ore, concentrate, sinter, and ferroalloys obtained from the five largest ferroalloys enterprises-producers. The amounts of of ferroalloys production, the weight of the used ore, concentrate, sinter, reducing agents, slag-forming materials and waste, as the carbon content in reducing agents, ore, concentrate, sinter, and ferroalloys production for one of this enterprises-manufacturers were determinated by using specific values of these amounts for calculations in 2021 due to the lack of data received from this manufacturer in 2021.

The methodology of calculating emissions in this category corresponds to Tier 3, described in [1]. In calculations, the scientific-research work "Development of methodological recommendations of greenhouse gas emission factors assessment by refining the data of the composition of reducing agents used in ferroalloys production and the carbon content in ore, slag-forming materials, and waste" [9] was used, applying the calculation methodology of the SE "UkrRTC "Energostal", which made possible to clarify the details of all components used as reducing agents, slag-forming materials, waste, and fluxes in production of various types of ferroalloys at all enterprises in Ukraine. In ferroalloys production, limestone is used as flux, emissions from the use of which are accounted in the total emissions from ferroalloys production in Table 4.19. Besides emissions from use of limestone in ferroalloys production are presented in A3.1.2 Determination of the amount of limestone and dolomite use.

For estimation of CH_4 emissions from ferroalloys production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.4.2.3 Uncertainties and time-series consistency

The key factors that determine uncertainty of the inventory results in this category are the uncertainty of:

– activity data of the enterprises (production of ferroalloys by type);

– data on the weight of the reducing agent used, of slag materials and waste, as well as on the carbon content in them;

– statistical activity data.

The uncertainty of activity data of the enterprises is estimated at 10.6%. The uncertainty of the data to estimate the weighted average rate of carbon dioxide emissions in ferroalloys production at all enterprises of the sector is estimated at 5%. The uncertainty of data to estimate the average weighted methane emission factor in ferroalloys production is 31.25%. The uncertainty of activity data for methane emission assessment is estimated at 5.25%. The uncertainty of estimates of carbon dioxide emissions in production of ferroalloys for 2021 was 11.7%. The uncertainty of estimates of methane emissions in production of ferroalloys for 2021 was 31.68 %.

4.4.2.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions in ferroalloys production:

- analysis of the time-series of activity data (ferroalloy production volumes) and emissions.

4.4.2.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 emissions for 2019 -2020 was made due to adjustment of the data of raw materials consumption for ferroalloys production according to the data obtained from enterprises.

Table 4.20 Recalculation of CO_2 emissions from ferroalloys production in 2021.

2.C.2 Ferroalloys production	**2019**	**2020**
CO_2		
Emissions (before recalculating), kt	1848.73	1308.11
Emissions (after recalculating), kt	1848.65	1313.08
EF (before recalculating), t/t	1.5615	1.53

2.C.2 Ferroalloys production	2019	2020
CO_2		
EF (after recalculating), t/t	1.5614	1.54
Difference,%	-0.005	0.38

4.4.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.4.3 Aluminum Production (CRF category 2.C.3)

4.4.3.1 Category description

This section is dedicated to aluminium production which is a potentially important source of carbone dioxide (CO_2), and CF_4 and C_2F_6 emissions in the countries where they are produced. At the only aluminum plant in Ukraine from 2011 to 2021, aluminum production was stopped due to lack of cost-effectiveness and high cost of electricity. Estimation of GHG emissions from 2011 till 2021 was no performed in this category. The data about aluminium production in Ukraine is confidential.

4.4.3.2 Methodological issues

Data of aluminium production was provided by the enterprise-producer. According to 2006 IPCC Guidelines [1] Tier 1 method for estimation of CO_2 emissions and Tier 2 method for estimation of CF_4 and C_2F_6 emissions from aluminium production, were used.

4.4.3.3 Uncertainties and time-series consistency

According to the activity data provided by producing enterprise aluminium has not been produced since 2010, so the uncertainties in this category were not calculated.

4.4.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in aluminium production.

4.4.3.5 Category-specific recalculations

In this category, no recalculations were made

4.4.3.6 Category-specific planned improvements

In this category, no improvements are planned.

4.4.4 Magnesium Production (CRF category 2.C.4)

There is no magnesium production in Ukraine, therefore emissions in this category are not estimated.

4.4.5 Lead Production (CRF category 2.C.5)

4.4.5.1 Category description

Lead is one of the softest and most ductile heavy metals. Lead uses in manufacture of protective sheaths of electric cables, sulfuric acid production equipment. Lead alloys are used for manufacture of bearings, batteries, they are used as a basis for manufacture of printing metal. The smelting process represents the reduction reaction of the lead oxide which produces CO_2. In this category, calculations of CO_2 emissions were performed for the entire time series since 1990. Table 4.21 shows the basic data of GHG inventory for carbon dioxide in lead production in Ukraine.

Table 4.21. The basic data on the results of GHG inventory in lead production in 2021

Category code	**2.C.5**
Lead Production, kt	28.82
Gas	CO_2
Emissions, kt eq.	14.99
Change in emissions compared to the previous year,%	-3.30
Change in emissions compared to the baseline year,%	-32.17
Emissions, % of the total emissions in the sector	0.03
Emissions, % of the total direct action GHG emissions in the sector	0.026
The key category	No
The level of detail for lead (Tier)	1
Emission factor, t/t	0.52
Method for determination of the emission factor for lead	D
Uncertainty of activity data, %	10
Uncertainty of the emission factor, %	50
Uncertainty of the emission estimation, %	50.99

4.4.5.2 Methodological issues

Data of lead production were obtained from SSSU basing on data of Index of industrial production 2021. For estimation of CO_2 emissions from lead production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.4.5.3 Uncertainties and time-series consistency

The uncertainty of activity data of the enterprises is estimated at 10 %. The uncertainty of data of the default carbon dioxide emission factor in lead production is estimated at 50%. The uncertainty of estimates of carbon dioxide emissions in lead production for 2021 was 50.99%.

4.4.5.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions from lead production.

4.4.5.5 Category-specific recalculations

In this category, no recalculations were made.

4.4.5.6 Category-specific planned improvements

In this category, no improvements are planned.

4.4.6 Zinc Production (CRF category 2.C.6)

4.4.6.1 Category description

Zinc is brittle metal, it melts at 419°C, it does not naturally exist as a native metal. Zinc extracted from polymetal ores containing 1-4% of Zn in the form of sulfide. Possessing anti-corrosion properties, zinc uses for galvanizing steel sheet, telegraph wires, pipes for various purposes, it is a component of some pharmaceuticals. CO_2 emissions from zinc production form during the smelting process. The data about zinc production in Ukraine is confidential. Between 1998 and 2005, there was no zinc production in Ukraine. Table 4.22 shows the basic data of the inventory for carbon dioxide in zinc production in Ukraine.

Table 4.22. The basic data on the results of GHG inventory in zinc production in 2021.

Category code	2.C.6
Zinc Production, kt	C
Gas	CO_2
Emissions, kt eq.	1.013
Change in emissions compared to the previous year,%	-3.30
Change in emissions compared to the baseline year,%	-95.82
Emissions, % of the total emissions in the sector	0.002
Emissions, % of the total direct action GHG emissions in the sector	0.0017
The key category	No
The level of detail for zinc (Tier)	1
Emission factor, t/t	1.72
Method for determination of the emission factor for zinc	D
Uncertainty of activity data, %	10
Uncertainty of the emission factor, %	50
Uncertainty of the emission estimation, %	50.99

4.4.6.2 Methodological issues

Data of zinc production were taken from SSSU basing on the data of Index of industrial production 2021. For estimation of CO_2 emissions from zinc production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.4.6.3 Uncertainties and time-series consistency

The uncertainty of activity data of the enterprises is estimated at 10 %. The uncertainty of data of the default carbon dioxide emission factor in zinc production is estimated at 50%. The uncertainty of estimates of carbon dioxide emissions in zinc production for 2020 is 50.99%.

4.4.6.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions in zinc production.

4.4.6.5 Category-specific recalculations

In this category, no recalculations were made.

4.4.6.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5 Non-energy Products from Fuels and Solvent Use (CRF category 2.D)

Emissions in this category are estimating as a result of the first use of fossil fuels as a product for primary purposes such as Lubricant, Paraffin Wax, Asphalt and Solvent use. The main CO_2 emissions occurs only from Lubricant and Paraffin Wax use. In other categories only the precursors and SO_2 emissions occurs. The subcategories in this category are not the key sources of emissions. The activity data collection, methodological issues as well as QA/QC procedures etc. by the categories included in this category are shown by each subcategory in relevant chapters.

4.5.1 Lubricant Use (CRF category 2.D.1)

4.5.1.1 Category description

Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. They can be subdivided into (a) motor oils and industrial oils, and (b) greases, which differ in terms of physical characteristics (e.g., viscosity), commercial applications, and environmental fate. The inter-annual deviations that occurs in lubricants use for 1996, 1997, 1998 was assosiated with start of the importation to Ukraine of lubricants use since 1996 as well as the changes in 2007 which occured due to sharp growth of production and importation of lubricants in Ukraine. Table 4.23 shows the basic data on the results of GHG inventory in lubricant use.

Table 4.23. The basic data on the results of GHG inventory in lubricant use in 2021.

Category code	2.D.1
Lubricant Use, TJ	8915.59
Emissions of CO_2, kt	130.76
Change in CO_2 emissions compared to the previous year,%	-1.58
Change in CO_2 emissions compared to the baseline year,%	-57.10
Emissions, % of the total emissions in the sector	0.26
Emissions, % of the total direct action GHG emissions in the sector	0.22
The key category	No
Detail level (Tier)	1
Emission factor, t/t	0.59
Method for determination of the emission factor	D
Uncertainty of activity data, %	9
Uncertainty of the emission factor, %	50.09
Uncertainty of the emission estimation, %	50.89

Activity data, emission factors, and GHG emissions throughout the entire time-series in this category are shown in Table A3.1.1.13, Annex 3.1.1.

4.5.1.2 Methodological issues

Estimation of emissions from lubricants use was carried out in accordance with 2006 IPCC Guidelines (Tier 1) with application of ODU and the default carbon content factor [1]. The data of lubricants non-energy consumption in 2021 was taken with using extrapolation method, based on data of crude oil production in Ukraine in 2020-2021, in accordance with 2006 IPCC Guidelines, Chapter 5.3 Resolving data gaps [1]. To avoid double counting between the Energy and IPPU sectors, data of lubricants non-energy consumption from 1990 till 2020 are not accounted in emission estimations in the "Energy sector". For 2014 - 2021, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of lubricants consumption.

4.5.1.3 Uncertainties and time-series consistency

The uncertainty of data of lubricants consumption obtained from statistical data is taken at 9%. The uncertainty of the default emission factors (ODU) is set at 50.09%. The uncertainty of CO_2 emissions from lubricant use in Ukraine amounts to 50.892%.

4.5.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation for GHG emissions in lubricant use.

4.5.1.5 Category-specific recalculations

In this category, no recalculations were made.

4.5.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5.2 Paraffin Wax Use (CRF category 2.D.2)

4.5.2.1 Category description

This category includes such products as petroleum jelly, paraffin waxes and other waxes, including ozokerite (mixtures of saturated hydrocarbons, solid at ambient temperature). Paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. Paraffin waxes are categorised by oil content and the amount of refinement. Solid paraffins are recovered from crude oil production in production of light (distillation) lubricating oils, and they are sub-classified based on oil content and purity. Waxes are used in a number of different applications, for example, in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g., candles). Table 4.24 shows the basic data on the results of GHG inventory in wax use.

Table 4.24. The basic data on the results of GHG inventory in solid paraffin wax use in 2021.

Category code	2.D.2
Solid Paraffin use, TJ	710.09
Emissions of CO_2, kt	10.41
Change in CO_2 emissions compared to the previous year,%	-0.41
Change in CO_2 emissions compared to the baseline year,%	- 91.52
Emissions, % of the total emissions in the sector	0.02
Emissions, % of the total direct action GHG emissions in the sector	0.018
The key category	No
Detail level (Tier)	1
Emission factor, t/t	0.590
Method for determination of the emission factor	D
Uncertainty of activity data, %	6.00
Uncertainty of the emission factor, %	100.12
Uncertainty of the emission estimation, %	100.305

Activity data, emission factors, and GHG emissions throughout the entire time-series in this category are shown in Table A3.1.1.14, Annex 3.1.1.

4.5.2.2 Methodological issues

Estimation of emissions from solid paraffins use was carried out in accordance with 2006 IPCC Guidelines (Tier 1) with application of ODU and the default carbon content factor [1]. Data of solid paraffins use were determined based on data of production, exports, and imports of paraffin waxes obtained from SSSU [2, 22]. For 2014 - 2021, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of paraffins consumption.

To convert consumption data in mass units into the conventional energy units (TJ), default coefficients of calorific value according to the Guidelines in Section 1.4.1.2, Chapter 1, Volume 2 (Energy) were used.

4.5.2.3 Uncertainties and time-series consistency

The uncertainty of data of production, exports, and imports of lubricants obtained from statistical data is estimated at 6%. The uncertainty of the default factors (ODU) and the carbon content is taken at the level of 100.12% due to the fact that the factors are associated with highly limited information of national use of solid paraffins. Thus, the uncertainty of CO_2 emission from solid paraffins use in Ukraine amounts to 100.305%.

4.5.2.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in paraffin wax use.

4.5.2.5 Category-specific recalculations

In 2021 in this category recalculation of CO_2 emissions for 2020 was made due to adjustment of the data of paraffin waxes use in accordace with data obtained from SSSU [2, 22].

Table 4.25 Recalculation of CO_2 emissions from Paraffin wax use in 2021.

2.D.2 Paraffin Wax Use	**2020**
CO_2	
Emissions (before recalculating), kt	10.03
Emissions (after recalculating), kt	10.45
Difference,%	-4.081

4.5.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5.3 Asphalt Production and Use (CRF category 2.D.3)

4.5.3.1 Asphalt roofing (CRF category 2.D.3.a.1)

4.5.3.1.1 Category description

Petroleum bitumen is produced by oxidation of residual products of direct distillation of crude oil and their mixtures with asphalts and extracts of oil production. Therefore, this bitumen is also called oxidized bitumen.

For roofing materials production, treating and coating oil bitumen are used. In the process of their production emissions of CO and NMVOCs occurs. No GHGs occurs in this category. Table 4.26 shows the basic data of the results of GHG inventory in construction and roofing bitumen production.

Table 4.26. The basic data on the results of GHG inventory in construction and roofing bitumen production in 2021.

Category code	**2.D.3.a.1**	
Bitumen Production, kt	C	
Gases	CO	NMVOC
Emissions, kt	0.0000025	0.0000013
Change in emissions compared to the previous year, %	-1.94	
Change in emissions compared to the baseline year, %	-99.93	
Emissions, % of the total emissions in the sector	0.0000069	0.0000012
Method for determination of the emission factor	D	D
Detail level (Tier)	1	1
Emission factor, n/t	0.00001	0.000005

4.5.3.1.2 Methodological issues

Data of production volumes of construction and roofing bitumen separately were obtained from enterprises-producers. Data of road petroleum bitumen and bitumen for special purposes production, as well as general information about petroleum bitumen production are presented in SSSU [2].

Estimation of CO and NMVOC emissions was conducted in accordance with 1996 IPCC Guidelines [5] (section 2.7.1.1), using the default emission factors for oxidized bitumen.

4.5.3.1.3 Uncertainties and time-series consistency

The uncertainty of CO and NMVOC emission estimation results was not determined in this category.

4.5.3.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions from construction and roofing bitumen production.

4.5.3.1.5 Category-specific recalculations

In this category, no recalculations were made.

4.5.3.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5.3.2 Road paving with asphalt (CRF category 2.D.3.a.2)

4.5.3.2.1 Category description

In the category Road paving, road bitumen is accounted for, which is produced by oxidation of products of direct oil distillation and selective separation of petroleum products (asphalts at deasphalting or selective purification extracts), as well as at compounding of these oxidized and non-oxidized products, or as a residue of direct oil distillation. GHG emissions take place in road bitumen production at enterprises and when paving asphalt. In road bitumen production, SO_2, NOx, CO, and NMVOC emissions take place, and while laying asphalt - only NMVOC. No GHGs occurs in this category. Table 4.27 shows the basic data on the results of GHG inventory in road paving with asphalt.

Table 4.27. The basic data on the results of GHG inventory in road paving with asphalt in 2021.

Category code	**2.D.3.a.2**			
Production of road bitumen, kt	75.1			
Gases	NOx	CO	NMVOC	SO_2
Emissions from production, kt	0.0027	0.015	0.0017	0.0013
Emissions from paving, kt			1.2	
Change in emissions compared to the previous year,%	44.98			
Change in emissions compared to the baseline year,%	-96.41			
Emissions at production, % of the total in the sector	0.011	0.041	0.0015	0.0023
Emissions at paving, % of the total in the sector			1.08	
Method for determination of the emission factor	D	D	D	D
Detail level (Tier)	1	1	1	1
Emission factor at production, t/t	0.0000356	0.0002	0.000023	0.0000177

Emission factor at paving, kg/t			0.016	

4.5.3.2.2 Methodological issues

Road bitumen production volumes was obtained from SSSU [2]. In accordance with 2013 EMEP/EEA recommendations [6] the default emission factors of GHG emissions for asphalt production were used.

4.5.3.2.3 Uncertainties and time-series consistency

The uncertainty of NO_x, CO, NMVOC and SO_2 emission estimation results was not determined in this category.

4.5.3.2.4 Category-specific QA/QC procedures

The general quality control and assurance procedures were applied to estimation of GHG emissions at road paving with asphalt.

4.5.3.2.5 Category-specific recalculations

In this category, no recalculations were made.

4.5.3.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5.4 Solvents Use (CRF category 2.D.3.b)

4.5.4.1 Category description

The category Solvents Use, accounts emissions from paints and solvents use in industry and households. Solvents and paints contain substances, use of which results in emissions into the air of non-methane volatile organic compounds (NMVOC). Besides, this sector also includes NMVOC emissions from production and processing of certain chemical products.

In the current inventory, in GHG emission estimations for the period of 1990-2014 results obtained in the framework of the scientific-research work "Development of methods for estimation determination of greenhouse gas emissions from use of varnishes and paints" (the performer - Innovation Center "Ecosystem") [14] were used.

NMVOC emissions in the Solvents Use category in 2021 amounted to 50.58 kt, having decreased compared to the baseline 1990 (274.46 kt) by -81.57%. The significant reduction in emissions is due to the sharp decline in oil processing and consumption of paints and varnishes for industrial and household purposes.

4.5.4.2 Varnishes and Paints Use (CRF category 2.D.3.b.1)

4.5.4.2.1 Category description

The category Varnishes and Paints Use includes emissions occurring in manufacturing processes associated with paints, varnishes, enamels, fillers, and primers use. The key sectors, technologies that involve use of these processes in Ukraine are: machine engineering, wood processing, repair and construction, and textile industry. As a result of doing business in these sectors, NMVOCs emitted into the air as vapor of volatile organic solvents at painting - 20-30%, while drying - the rest of the volatile component [4-6].

Use of paints and varnishes (coatings) in Ukraine is in general technologically homogeneous. NMVOC emissions from the use of coatings depend of the following factors: the coating method, productivity of the production equipment, and coatings composition. They are calculated separately for decorative and industrial coatings, due to significant technological differences [15].

In accordance to results of the current inventory, NMVOC emissions from paints use in Ukraine in 2021 amounted to 39.55 kt, having decreased compared to the baseline 1990 (154.16 kt) by 74.34% due to the significant reduction in activities related to use of coatings of all types with the exception of those used for painting rolled metal.

4.5.4.2.2 Methodological issues

In this inventory, for the time series of 1990 - 2021 NMVOC emissions from use of paints was estimated in accordance with the Methodology for determination of greenhouse gas emissions from use of varnishes and paints, developed in 2013 within the scientific-research work [14], which was implemented by the Innovation Center "Ecosystem".

The basis of NMVOC emission calculations in this category, in accordance with [14], was the principles described in 2013 EMEP/EEA [6], and the emission equation, which meets the requirements and methodological approaches of Tier 2. NMVOC emissions are calculated according to the equation:

$$Q_t = \left(P \cdot \frac{K_{org}}{100} \cdot \frac{K_{Porg}}{1000}\right) + \left(P \cdot \frac{K_w}{100} \cdot \frac{K_{Pw}}{1000}\right), \quad (1)$$

where: Q_t - volume of NMVOC emissions in the inventory year, t;

P - set amount of coating consumption;

K_{org} - share of organically soluble coatings in the product consumption structure;

K_w- share of water soluble coatings in the consumption structure;

K_{Porg} - NMVOC emission factor for organically soluble coatings;

K_{Pw} - NMVOC emission factor for water soluble coatings.

Due to the nature of coating use and characteristics of the industry structure in Ukraine, as well as in view of EMEP/EEA recommendations, in equation (1) the optimal format for disaggregation of activity data in the category of coating use into subcategories is used, namely:

- by the key uses of coatings, which at the same time are the key air pollutants in this category: decorative coatings (construction and building, household use), as well as industrial coatings (protective coatings for metal surfaces, treatment and painting of timber, automotive, repair of motor vehicles, painted rolled metal, other industrial use);
- by solvent type (organic-based coatings, water-based coatings);
- by the coating use structure according to the type of use and the type of solvent;
- by the inventory number in the time-series of 1990-2021.

The basis of the activity data is data of the amount of coating consumption in Ukraine in 1990 - 2021 taken based on production, exports, and imports data obtained from SSSU [2, 22].

NMVOC emission factors (K_{Porg} and K_{Pw}). Given that after work using coatings NMVOCs contained in the coatings get into the air in full, the NMVOC emission factor is their content in coatings. In Ukraine, there is no regulatory or technical documentation that would regulate the limit parameters of volatile organic compounds in coatings. The only exceptions are oil paints, for which the ceiling standards of the volatile matter are set in accordance with GOST 10503-71, GOST 8292-85. For thick-milled oil paints, the figure is between 6 and 11%, for ready to use oil paints - from 12 to 19%. For oil paints, the volatile substance is mostly an organic solvent. Accordingly, we assume that the limits of volatile substance content in oil paints meet the limits of volatile organic substances in the commercial product. At the same time, starting from 2007, according to the State Classifier of Industrial Products SCIP 016-1997, a number of adjustments were introduced into the statistical reporting on the commodity group "Paints and Varnishes Dissolved in a Different Medium", for statistical reporting of organically soluble coating producers.

Scientific-research work [14] analyzes and systematizes the state standards, as well as producers data of the content of volatile organic compounds in paints in Ukraine, the results of the research are summarized in Table 4.28.

Table 4.28. Content of volatile organic compounds in coatings in Ukraine

Type of coating	The sector where the coating is applied	NMVOC emission factor, g/kg	
		Organically soluble *(K_{Porg})*	Water soluble *(K_{Pw})*
Decorative coating	I*	230	33
	II*	230	33
Industrial coating	III*	740	33
	IV*	800	33
	V*	500	33
	VI*	720	33
	VII*	480	33
	VIII*	740	33

**I - for construction and building (professional coating); II - household use of coating (non-professional coating); III - protective covers for metal surfaces; IV - treatment and painting of timber; V - automotive; VI - repair of motor vehicles of all kinds; VII - painted rolled metal; VIII - other industrial coating.

4.5.4.2.3 Uncertainties and time-series consistency

For emissions in this category, uncertainties were not estimated.

4.5.4.2.4 Category-specific QA/QC procedures

For estimation of emissions in the category, the following quality control procedures were applied:

- comparison of activity data from different sources;
- comparison of emission along the time-series and analysis of activity data trends;

4.5.4.2.5 Category-specific recalculations

In this category, no recalculations were made.

4.5.4.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5.4.3 Degreasing and Dry Cleaning (CRF category 2.D.3.b.2)

4.5.4.3.1 Category description

NMVOC emissions in this category are related to technical kerosene and white spirits use for degreasing, as well as to trichlorethylene and tetrachlorethylene (perchlorethylene) use by dry-cleaning companies. NMVOC emissions from degreasing and dry cleaning processes in 2021 amounted to 2.14 kt, which is 88.38% less than the same indicator for 1990 (18.41 kt). Emission data for the entire time series are displayed in Fig. 4.7.

Decrease of emissions is due to a sharp decline in white spirit and technical kerosene production, which is not set-off by the slight increase of imports in this commodity group.

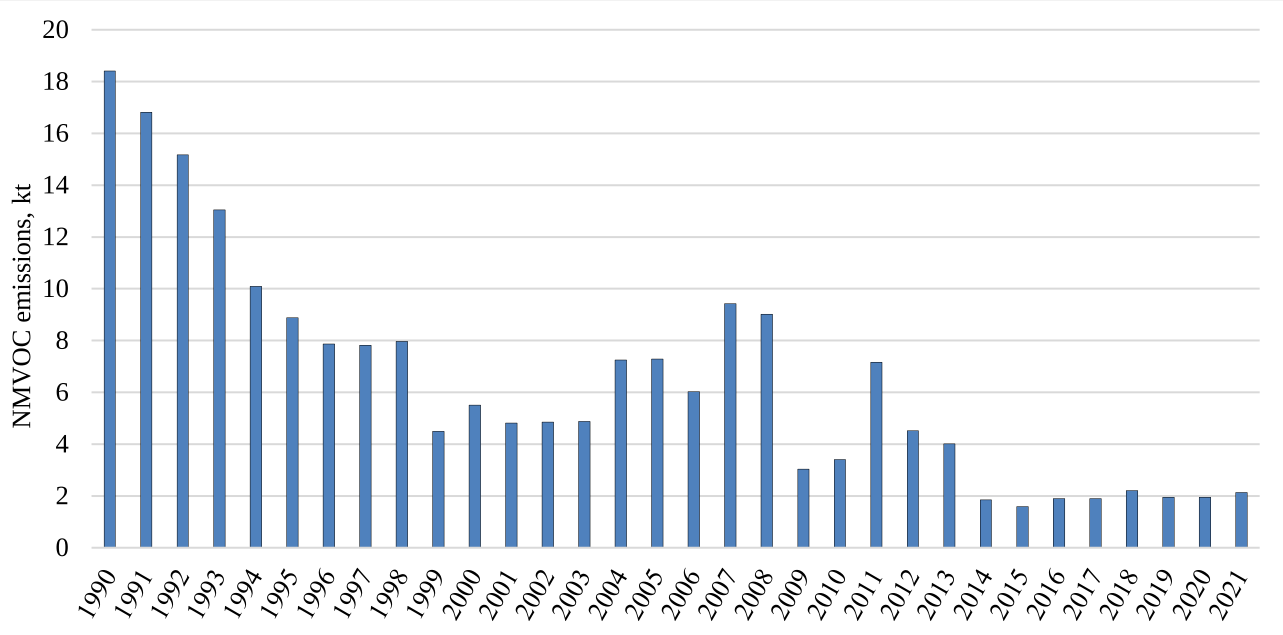


Figure 4.7. NMVOC emissions from degreasing and dry cleaning

4.5.4.3.2 Methodological issues

To calculate NMVOC emissions from degreasing processes, data on final consumption in Ukraine of the most common degreasing means are needed: white spirit and technical kerosene. The data of white spirit and technical kerosene were taken from SSSU basing on the data of Index of industrial production 2021. Data of trichlorethylene and tetrachlorethylene (perchlorethylene) imports were provided by SSSU [22]. The NMVOC emission factor for degreasing agents was taken as default value of 1.0; for chemicals used in dry cleaning - 0.8, according to [16].

4.5.4.3.3 Uncertainties and time-series consistency

For emissions in this category, uncertainties were not estimated.

4.5.4.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions in the category.

4.5.4.3.5 Category-specific recalculations

In this category, no recalculations were made.

4.5.4.3.6 Category-specific planned improvements

In this category, no improvements are planned.

4.5.4.4 Chemical Products: Production and Processing (CRF category 2.D.3.b.3)

4.5.4.4.1 Category description

The category covers NMVOC emissions from production and processing of various chemical products. In this inventory, estimation of NMVOC emissions from the following industries are included:

- oil refining;
- production of benzene and xylene;
- production of paints and varnishes;

- production of chemical fibers and threads;
- manufacture of glass fibers
- production of rubber products, tire, and rubber footwear.

Due to the fact that Ukraine has a well-developed chemical industry, NMVOC emissions in this category are significant (petrol oil, cyclohexane, acetone, cyclohexanone, etc.). In 2021, NMVOC emissions from production and processing of chemical products amounted to 8.89 kt, which is 91.27% less in relation to the baseline 1990 (101.9 kt). The emissions decrease in the periods of 1990 - 2000 and 2004 - 2021 are due to the persistent downward trend in oil refining in Ukraine. Detailed information of emissions in the category is presented in Fig. 4.8.

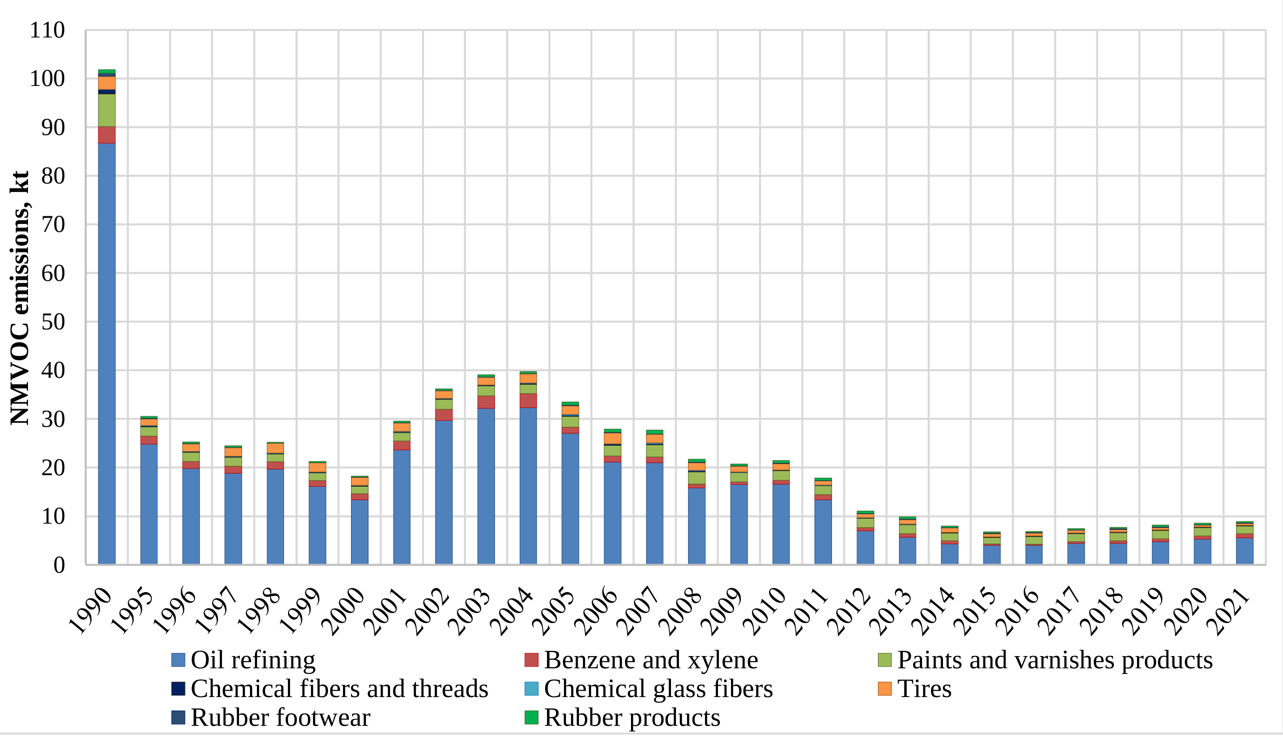


Figure 4.8. NMVOC emissions from chemical production and processing

4.5.4.4.2 Methodological issues

The data of volumes of chemical production and were taken according to SSSU [2]. The amounts of primary oil refining and chemical glass fibers were taken from SSSU basing on the data of Index of industrial production 2021.

Due to the fact that there is insufficient information regarding the calculation of the national emission factors in this category, to assess NMVOC emissions, emission factors by industry types listed in the inventory of the Republic of Belarus (Table 3.1 [17]) were used, which are similar to Ukrainian chemical industry technologies.

4.5.4.4.3 Uncertainties and time-series consistency

For emissions in this category, uncertainties were not estimated.

4.5.4.4.3 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions.

4.5.4.4.5 Category-specific recalculations

In 2021 in this category recalculation of NMVOC emissions for 2017 - 2020 was made due to adjustment of the data of chemical fibers and threads in accordace with data obtained from SSSU [2].

Table 4.29 Recalculation of NMVOC emissions from Chemical Products: Production and Processing in 2021.

2.D.3.b.3 Chemical Products: Production and Processing	**2017**	**2018**	**2019**	**2020**
NMVOC				
Emissions (before recalculating), kt	7.51	7.762	8.19	8.63
Emissions (after recalculating), kt	7.50	7.756	8.17	8.61
Difference,%	-0.17	-0.07	-0.15	-0.16

4.5.4.4.6 Category-specific planned improvements

In this category, no improvements are planned.

4.6 Electronics Industry

In Ukraine, the electronics industry, which includes production of flat panel displays on thin film transistors (TFT-FPD) and photovoltaic cells (PV) are absent. Ukraine only conducts SKD assembly of photovoltaic panels. There are no emission assessment in this category.

4.7 Product Uses as Substitutes for Ozone-Depleting Substances (CRF category 2.F)

In this section, estimation of HFC emissions used in refrigeration and air conditioning systems, foam blowing agents, fire protection, aerosols, and solvents was made.

Inventory of HFC and PFC emissions in this category was conducted in accordance with the scientific-research works: by the Ukrainian Research Institute of Medicine and Transport of the Ministry of Health of Ukraine "Development of methods of estimation and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride"[7] and by Cherkasy NIITEKHIM" - "Development of methods of estimation and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride" [13]. The studies clarified the details of all components used as refrigerants, blowing agents, fire protection agents, and gas propellants, as well as to clarify activity data and emission factors as a result of their application in manufacture, installation, and operation of the equipment where they are used.

Since HFCs and PFCs are not produced in Ukraine, potential emissions of these gases are determined only by their imports and exports.

4.7.1 Refrigeration and Air Conditioning Systems

4.7.1.1 Refrigeration Equipment

4.7.1.1.1 Category description

The category of refrigeration equipment includes domestic, commercial, industrial, and transport (including maritime) equipment (systems, installations, machinery, plants, etc.). In 2021, the level of disaggregation of the refrigeration equipment category was deepened to four key subcategories.

In 2021 in subcategory of domestic refrigerators only manufacturer in Ukraine, which as a refrigerant used isobutane R-600a and HFC-134a to check tightness of evaporator units of domestic refrigerators ceased its activities, therefore in 2021 refrigerants for domestic refrigerators were not consumed.

More than 20 producers in Ukraine manufacture commercial and industrial refrigeration equipment. As part of the NIR preparation, industrial activity of producers of cooling systems whose production structure is dominated by autonomous systems was analyzed.

In production of autonomous commercial equipment, they use HFC-134a and HFC-404a, in centralized systems of commercial and industrial refrigeration equipment they use primarily HFC-404a, which is the three-component mixed cooling agent of HFC-125/HFC-143a/HFC-134a.

As the refrigerants in transport refrigeration HFC-134a, HFC-404a and since 2017 HFC-406a are used.

In accordance with provisional main findings identified by the ERT calculations of emissions from disposal in commercial, domestic and transport refrigeration were made.

Data on activities in the refrigeration equipment category are based on data received from refrigeration equipment manufacturers, as well as the data obtained from SSSU. Table 4.30 summarizes results of GHG inventory in production and operation of refrigeration equipment in Ukraine.

Table 4.30 Basic data on results of GHG inventory in production and operation of refrigeration equipment in Ukraine in 2021.

Category code	**2.F.1.A**			**2.F.1.B**	**2.F.1.C**			**2.F.1.D**			
Types of refrigeration equipment	**Commercial**			**Domestic**	**Industrial**			**Transport**			
Gas*	**HFC-134a**	**HFC-125**	**HFC-143a**	**HFC-134a**	**HFC-134a**	**HFC-125**	**HFC-143a**	**HFC-134a**	**HFC-125**	**HFC-143a**	**HFC-32**
Activity data											
Filled into new manufactured products (primary filling + tightness test), t	75.00	5.1	6.00	0.0	11.44	0.0014	0.0016	2.3	0.77	0.91	0.0
HFC-balance after the initial filling, t	73.50	5.04	5.88	0.0	11.1	0.0013	0.0016	2.3	0.81	0.96	0.0
Amount of HFC in exported equipment, t	13.51	0.0068	0.0058	0.0	2.55	-	-	-	-	-	-
Amount of HFC in imported equipment, t	16.93	8.53	6.76	24.03	1.8	0.35	0.28	0.004	0.043	0.05	0.0
In operating systems (average annual stocks)	375.31	71.12	60.97	1071.91	44.5	3.14	1.87	5.63	3.2	3.71	0.001
Category characteristics and estimated factors											
Key category	L/T										
Detail level (Tier)	2a	2a	2a	2b	2b	2a	2b	2a	2a	2a	2a
Method for determination of the emission factor	D	D	D	D	D	D	D	D	D	D	D
Emission factor at primary (initial) filling,%	2	2	2	0.5	3	3	3	2	2	2	2
Emission factor when testing equipment for tightness,%	HFCs are not applied			100	HFCs are not applied						
Emission factor at operation of the equipment,%	15	15	15	0.5	25	25	25	15	15	15	15
Disposal emission factor,%	80	80	80	70	100	100	100	50	50	50	50
Average life of equipment	15	15	15	18	25	25	25	15	15	15	15
GHG emissions											
HFCs emissions											

Category code	**2.F.1.A**			**2.F.1.B**	**2.F.1.C**			**2.F.1.D**			
Types of refrigeration equipment	**Commercial**			**Domestic**	**Industrial**			**Transport**			
Gas*	**HFC-134a**	**HFC-125**	**HFC-143a**	**HFC-134a**	**HFC-134a**	**HFC-125**	**HFC-143a**	**HFC-134a**	**HFC-125**	**HFC-143a**	**HFC-32**
at the primary (initial) filling of the equipment(from manufacturing), t	1.5	0.1	0.12	0.0	0.34	0.000042	0.000048	0.046	0.015	0.018	0.0
at exploitation of the equipment(from stocks), t	56.3	10.66	9.15	5.36	11.13	0.785	0.468	0.845	0.48	0.556	0.00021
from liquidation of the equipment, t	46.06	4.94	5.62	75.31	-	-	-	0.232	0.33	0.388	-
Emissions of HFCs in the refrigeration equipment category, total, t	103.9	15.71	14.88	80.67	11.47	0.785	0.468	1.12	0.823	0.962	0.00021
Global Warming Potential (GWP), t $CO_{2\text{-eq.}}$ /t	1430	3500	4470	1430	1430	3500	4470	1430	3500	4470	675
GHG emissions, kt of $CO_{2\text{-eq}}$	148.5	54.98	66.53	115.35	16.4	2.75	2.09	1.61	2.88	4.3	0.0001
Change in emissions compared to the previous year,%	0.75	-3.53	-3.96	25.57	-1.64	-15.45	-11.45	-26.55	-42.3	-42.2	-50.0
Emissions, % of the total direct action GHG emissions in the sector	0.46			0.2	0.036			0.015			
Uncertainty level estimation											
Uncertainty of activity data, %	34.02			26.13	39.78			39.49			
Uncertainty of the emission factor, %	24.37			20.6	32.78			24.37			
Total uncertainty of the emission estimation, %	41.85			33.27	51.54			46.40			

** Mixed fluoro-gases are represented by components.*

4.7.1.1.2 Methodological issues

4.7.1.1.2.1 Commercial, domestic and industrial refrigeration

Estimation of hydrofluorocarbon emissions from domestic, commercial and industrial refrigeration for production, operation and liquidation of refrigeration equipment was performed with using method 2a and 2b.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

Activity data were obtained or calculated on the basis of the raw data obtained from enterprises-producers of refrigeration equipment. Increase in the use of HFC-134a, HFC-125 and HFC-143a in 2021 explains by increase in imports of HFC-containing equipment according to the statistics of imports of the State Custom Service of Ukraine.

For 2014 - 2021, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of hydrofluorocarbons consumption, export and import.

Estimation of HFC emissions in production was based on data of the enterprises-producers on the amount of HFCs used for initial filling and tightness testing of the equipment (if such technical operation was executed). When calculating the total of HFCs in the current stock of equipment, the average factor of filling a piece of equipment with refrigerant is used, which was adopted taking into account the amount of filling for each type of cooling systems. Estimation of emissions from operation of imported equipment, which constitutes the current HFC bank in the refrigeration equipment category, was made based on the stock of refrigeration equipment imported into Ukraine by the key types of equipment and the estimated total content of the cooling agent based on the relevant factors. The calculations of emissions from disposal in domestic refrigeration was calculated using the default factor, in accordance with IPCC 2006 guidelines[1] and scientific-research work [13]. The calculation of disposal emissions from domestic refrigeration was performed since 2017 in relation with use of assumed life time of the domestic equipment as 18 years, what is related with unstable economic situation in Ukraine which influenced on the reducing of the purchasing ability of the population and accordingly the increase of average lifetime of the refrigerators due to the lack of replacement of refrigerators and an increase in the amount of services provided to the population for the repair of domestic refrigerators in accordance with expert assessment [23] of the scientific research institute Cherkassy NIITECHIM what allow to use of 18 years as lifetime which does not contradict with IPCC 2006 ranges from 12 to 20 years.

4.7.1.1.2.2 Transport refrigeration

Estimation of emissions from manufacturing, exploitation and disposal in transport refrigeration was carried out in accordance with IPCC 2006 guidelines[1] according to the Tier 2a using the default factor. The activity data were obtained from the main companies using HFCs as a refrigerant in automobile and railroad refrigerators for 2014 - 2021, such as "Ukrzaliznytsia" and largest certified companies of the installation of refrigeration equipment on motor vehicles, with using the method of extrapolation to determine the amount of used HFCs in 2000 – 2014 in accordance with IPCC 2006, Chapter 5: Time series consistency, Section 5.3 Resolving data gaps.

Emissions in 1990-1999 years did not occurred because according to customs statistics HFCs used as refrigerant in refrigerating equipment to Ukraine were not imported, as indicated in scientific-research work [13].

4.7.1.1.3. Uncertainties and time-series consistency

The uncertainty level of the activity data and emission factors in the refrigeration equipment category was determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factors of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13], based on the specific characteristics of source and calculated data formation in 2020.

The calculated uncertainty of the activity data in the category of domestic refrigeration equipment in 2021 amounted to 26.13%, of commercial refrigeration systems - 34.02%, of industrial cooling systems - 39.79% and transport refrigeration – 39.49%. The uncertainty of the default HFC emission factors used in the subcategory of domestic refrigeration equipment in 2021 was 20.6%, commercial refrigeration systems - 24.37%, industrial cooling systems - 32.78% and transport refrigeration - 24.37%. The total emission estimation uncertainty in 2020 made up in the domestic refrigeration sub-category - 33.27%, commercial refrigeration systems - 41.85%, industrial cooling systems - 51.54% and transport refrigeration – 46.40%.

4.7.1.1.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.7.1.1.5. Category-specific recalculations

In 2021 in this category recalculation of HFC-125 emissions for the 2020 was made due to correction of the mechanical misprint occurred by entering data of import of HFC and HFC-containing equipment for industrial refrigeration systems.

Table 4.31 Recalculation of emissions from Industrial refrigeration in 2000.

2.F.1.C Industrial refrigeration	**2020**
HFCs	
Emissions (before recalculating), kt	24.37
Emissions (after recalculating), kt	22.29
Emission difference,%	-8.55

4.7.1.1.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.7.1.2 Mobile Air-Conditioning

4.7.1.2.1 Category description

The object of HFC emission estimates in this category is mobile air-conditioning systems (SAC) for road, railway, and maritime transport. The key consumer niche in this category is mobile air-conditioning systems for road transport (99%).

In 2022, 11 vehicle manufacturers operated in Ukraine (passenger cars, trucks, and buses). The level of capacity utilization of the existing enterprises and, accordingly, the volume of production and sales of domestically produced vehicles in the period under review incresed by 45% compared with the previous year. Manufacture of vehicles equipped with air-conditioning decreased in the reporting year.

The refrigerant used in automotive and bus air conditioning systems was exclusively HFC-134a.

In accordance with provisional main findings identified by the ERT calculation of emissions from disposal in Mobile Air Conditioning was made.

In Ukraine, production of transport air-conditioning (for railway transportation, heavy vehicles in the construction and mining industries) is performed by six companies, three of them use HFC-134a, HFC-407Cc in production of air-conditioning systems.

Manufacture of air conditioning systems for river and marine vehicles in 2021 in Ukraine was performed by 2 producers. They mainly used fresh or sea water as refrigerants for main air cooling.

In autonomous air-conditioning systems for marine and river vessels, HFC-407c and R22 prevail as refrigerants. The second commodity producer filled air conditioning systems with refrigerant R22. Table 4.32 summarizes results of GHG inventory in production and operation of vehicle SACs in Ukraine.

Table 4.32 Basic data on results of GHG inventory in production and operation of vehicle SACs in Ukraine in 2021

Category code	2.F.1.E				
Category (type of equipment)	**Mobile Air Conditioning Systems**				
	for automotive vehicles	for railway transport			for sea and river transport
Gas	**HFC-134a**	**HFC-32**	**HFC-125**	**HFC-134a**	
Activity data					
Use of the refrigerant in SAC manufacturing (primary filling), t	2.189	0.056	0.056	0.141	NA
HFC stock after the initial filling, t	2.178	0.056	0.056	0.140	NA
Amount of HFCs in exported SACs as parts of vehicles, t	0.0	0.00029	0.00032	0.0036	NA
Amount of HFCs in imported SACs as parts of vehicles, t	31.3	0.00055	0.00059	0.0012	NA
HFC stock in exported SACs as parts of vehicles, t	331.131	0.182	0.160	1.15	NA
Category characteristics and estimated factors					
Key category	L/T				
Detail level (Tier)	2a	2a			2a
Method for determination of the emission factor	D	D			D
Emission factor at primary (initial) filling,%	0.5	0.5			0.7
Emission factor when testing equipment for tightness,%	HFCs are not used				
Emission factor at operation of the equipment,%	15	15			5
Disposal emission factor,%	70	70			70
Average lifetime of the equipment, years	18	25			15
GHG emissions					
HFCs emissions					
at the primary (initial) filling of the equipment, t	0.011	0.00028	0.00028	0.0007	NA
at operation of the equipment, t	49.67	0.027	0.024	0.172	NA
at liquidation of the equipment, t	43.74	-	-	-	NA
Emissions of HFCs in category, total, t	93.42	0.0276	0.024	0.173	NA
GWP, t CO_{2-eq} /t	1430	675	3500	1430	NA
GHG emissions, kt of CO_{2-eq}	133.59	0.019	0.085	0.247	NA
Change in emissions compared to the previous year, %	26.52	24.12	32.53	-3.57	NA
Emissions, % of the total direct action GHG emissions in the sector	0.23	0.0006			NA
Uncertainty estimation					
Uncertainty of activity data, %	26.13	34.33			NA
Uncertainty of the emission factor, %	23.45	29.15			NA
Uncertainty of the emission estimation, %	35.11	45.04			NA

4.7.1.2.2 Methodological issues

Estimation of emissions of hydrofluorocarbons in the category of mobile air-conditioning systems was performed for production and operation of air conditioning systems as parts of vehicles using Tier 2a approach. Desaggregation objects in this category were SACs for vehicles and rail transport.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

Estimation of emissions in production was based on data of the producing companies on the amount of HFCs used for initial SAC filling and tightness testing of the equipment (if such a technical operation was executed). When calculating the total of HFCs in the current stock of vehicles, the average coefficient of filling a piece of equipment with refrigerant was used, which was adopted taking into account the amount of filling for each type and class of SAC. Estimation of emissions from operation of SACs imported are part of vehicles, which constitutes the current HFC bank in this category, was made based on the stock of vehicles imported into Ukraine by the key types of equipment and the estimated total content of HFCs in it based on the relevant factors. Estimation of emissions from liquidation of equipment was carried out in accordance with IPCC 2006 guidelines[1] using the default factor.

Official data of the SSSU [22] were used to calculate HFC emissions from imported vehicles. The calculation did not include automobiles "VAZ", "GAZ", "UAZ", "Daewoo" produced in Russia or Uzbekistan, as well as cars of domestic and foreign brands produced in Ukraine.

Activity data for the SAC sub-category for rail transport and heavy machinery were calculated based on input national statistics on exports and imports, as well as on production of rail vehicles[1, 23]. According to the data obtained from enterprises in 2020 there was no HFC-125 and HFC-32 use for primary filling in rail transport and heavy machinery. In 2021 the use of the HFC-125 and HFC-32 for primary filling in rail transport and heavy machinery resumed in accordance with data obtained from enterprises. For 2014 - 2021, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of hydrofluorocarbons consumption, export and import.

Calculation of emissions for railway transport from production was performed on the basis of the data of the amount of HFCs used for the initial SAC filling. When calculating the total HFC stock in the operated fleet of railway transport, the maximum refrigerant filling of the equipment unit factor (6 kg) was used, which was adopted taking into account data obtained from experts in the field of air conditioning and ventilation systems in railway transport.

The use of the 18 years as the assumed life time for automotive vehicles in estimates for subcategory Mobile Air Conditioning is related to the fact that, according statistical studies, in the current unstable economic situation in Ukraine, the small sales of new cars and the insignificant importation of old cars into the country led to a significant aging of the vehicle fleet, resulting in an average lifetime of cars from 17 to 20 years. Taking into account the national circumstances like unstable economic situation after the collapse of the USSR in 1991 automobile vehicles in Ukraine were producted at only one plant, which does not produces cars with air-conditioned equipment till 2000. In accordance with scientific research work [13] the import of the air conditioned cars in Ukraine starts in 1998. Due to the fact that data of imports of HFCs in automobile vehicles in Ukraine for 1998-1999 are not available, the data obtained from SSSU[22] of the total import of cars from Europe and other countries were used, which covers all imports, both public and private. Since the import of cars in 1998 - 1999 compared to 2000 was not significant, and accordingly the use of HFC in automotive air conditioners was also insignificant, a conservative decision was taken into account for HFCs emissions use from automo-bile air-conditioners beginning from 2000, since there was more accurate information starting from the year 2000. And according to the data received from the SSSU [22], import of cars before 1998 was very insignificant, it was assumed that cars with air conditioners containing HFCs were not imported to Ukraine until 1998. But, according to recommendation of ARR 2017 (I.16, 2017) basing on information of the import of cars in 1998 - 1999, obtained from SSSU [22] and using extrapolation methods, the calculation of emissions from Mobile air conditioning systems in automotive vehicles for the period of 1998 – 1999 was made. The values of the bank in existing equipment for 2000 was calculated taking into account the estimates of HFCs included in imported automobile vehicles in 1998 and 1999 basing on the data of the total import of cars obtained from the SSSU [22] in accordance with scientific-research work [13].

4.7.1.2.3. Uncertainties and time-series consistency

The uncertainty level of the activity data and emission factors in the mobile air-conditioning system (SAC) category was determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factor of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13].

For each SAC category (road, railway vehicles), the specific uncertainty factors that affected calculation of the uncertainty level of the activity data and emission factors in 2021 were determined.

The uncertainty level of activity data in the SAC subcategory for the road transport in 2021 amounted to 26.13%, that of default emission factors – 23.45%, the total emission estimation uncertainty for the SAC category for road transport accounted for 35.11%.

The uncertainty level in the SAC sector for road transport in 2021 remained at the level of the previous year: the uncertainty of activity data – 26.13%, the default emission factors – 23.45%, the total emission estimation uncertainty in the sub-category – 35.11%.

The key factors contributing into uncertainty of activity data estimation in the SAC subcategory of railway transport are:

- the difficulty of assessing the amount of actually operated railway vehicles with HFC-containing air conditioning systems during the reporting year,
- the difficulty of identifying the amount of imported railway transport vehicles equipped with SACs with HFC refrigerants.

The uncertainty level of activity data in the SAC subcategory for the railway transport in 2021 amounted to 34.33%, that of default emission factors – 29.15%, the total emission estimation uncertainty for the SAC category for railway transport accounted for 45.04%.

4.7.1.2.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.7.1.2.5. Category-specific recalculations

In this category, no recalculations were made.

4.7.1.2.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.7.1.3. Stationary Air Conditioning

4.7.1.3.1 Category description

The currently available in Ukraine stock of equipment for stationary air conditioning (SAC) includes: stationary domestic (residential), semi-industrial, and industrial air conditioning systems (for non-domestic purposes).

The key type of air-conditioning equipment is domestic split systems. They are not produced in Ukraine, and the consumer demand in this market segment is met entirely due to importation of the equipment. In small volumes, domestic mobile floor air conditioners are imported to Ukraine.

To determine GHG emissions from exploitation of imported domestic, semi-industrial, and industrial air conditioning systems, we used data from enterprises.

The customs sampling object was stationary air conditioning systems of various types, namely:

- domestic split systems and mobile floor air conditioners;
- semi-industrial conditioning systems (external units, systems containing refrigeration units);
- industrial air conditioning systems, including autonomous (with a built-in refrigeration unit) ones.

In accordance with provisional main findings identified by the ERT calculation of emissions from disposal in Stationary Air Conditioning was made. The input data characterizing the status of the stationary air conditioning category, as well as data on results of the GHG inventory in 2021 in Ukraine are summarized in Table 4.33.

Table 4.33 Basic data on results of GHG inventory in production and operation of stationary air-conditioning equipment in Ukraine in 2021.

Category code	**2.F.1.F**						
Category (type of equipment)	**Domestic air conditioners (split systems, floor domestic air-conditioners)**			**Semi-industrial air conditioners**			
Gas*	**HFC-32**	**HFC-134a**	**HFC-125**	**HFC-32**	**HFC-125**	**HFC-134a**	**HFC-143a**
Activity data							
Use of a refrigerant in equipment manufacturing (primary filling + tightness test), t When testing tightness, HFCs are not used	-	-	-	-	-	-	-
HFC-balance after the initial filling, t	-	-	-	-	-	-	-
Amount of HFC in exported equipment, t	-	-	-	-	-	-	-
Amount of HFC in imported equipment, t	510.09	-	388.24	43.27	29.55	16.79	0.003
HFC balance in operated equipment, t	5360.79	36.54	3144.5	374.89	217.49	150.82	3.2
Category characteristics and estimated factors							
Key category	L/T						
Detail level (Tier)	2a	2a	2a	2a	2a	2a	2a
Method for determination of the emission factor	D	D	D	D	D	D	D
Emission factor at primary (initial) filing,%	0.7	0.7	0.7	1.0	1.0	1.0	1.0
Emission factor when testing equipment for tightness,%	HFCs are not used						
Emission factor at operation of the equipment,%	5	5	5	15	15	15	15
Disposal emission factor,%	70	70	70	70	70	70	70
Average lifetime of the equipment, years	15	15	15	25	25	25	25
GHG emissions							
HFCs emissions							
at the primary (initial) filling of the equipment (from manufacturing), t	-	-	-	-	-	-	-
at exploitation of the equipment(from stocks), t	268.04	1.83	157.22	56.23	32.62	22.62	0.480
from liquidation of the equipment, t	13.76	1.12	13.8	-	-	-	-
Emissions of HFCs in the air conditioning category, total, t	281.8	2.95	171.02	56.23	32.62	22.62	0.480
GWP, t $CO_{2\text{-eq}}$/t	675	1430	3500	675	3500	1430	4470
GHG emissions, kt of $CO_{2\text{-eq}}$	190.21	4.213	598.58	37.96	114.18	32.35	2.144
Change in emissions compared to the previous year,%	8.92	-16.21	15.15	-3.91	-1.64	-4.35	-14.93
Emissions, % of the total direct action GHG emissions in the sector	1.36			0.32			
Uncertainty level estimation							
Uncertainty of activity data, %	20.80			44.44			
Uncertainty of the emission factor, %	14.14			29.93			
Uncertainty of the emission estimation, %	25.15			51.96			

** Mixed fluoro-gases are represented by components.*

4.7.1.3.2 Methodological issues

Estimation of emissions of hydrofluorocarbons in this category was carried out using method 2a.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

Activity data were obtained from State Custom Service of Ukraine on import and export of air-conditioning equipment in 2021 and from companies producing conditioning equipment. For 2014 - 2021, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] was taken into account in adjustment of amounts of hydrofluorocarbons consumption, export and import.

When calculating the total of HFCs in the current stock of equipment, the average coefficient of filling a piece of equipment with refrigerant is used, which was adopted taking into account the amount of filling for each type and capacity class of SAC. For domestic air conditioners, the factor of 1.5 kg/unit was used, for semi-industrial and industrial ones - 5 kg/unit of equipment.

Estimation of emissions from operation of imported equipment, which constitutes the current HFC bank in this category, was made based on the stock of equipment imported into Ukraine by the key types of equipment and the estimated total content of HFCs in it based on the relevant factors.

Estimation of emissions from liquidation of equipment was carried out in accordance with IPCC 2006 guidelines[1] using the default factor.

Decrease in the use of HFC-134a and and HFC-143a, as well as an increase of HFC-125, HFC-32 in 2021 explains by changes in importation of HFC-containing equipment according to the statistics of imports of the State Custom Service of Ukraine.

4.7.1.3.3. Uncertainty factors and time-series

The uncertainty level of the activity data and emission factors in the air-conditioning system category was determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factors of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13].

For each sub-category of stationary air conditioning systems, the specific uncertainty factors that affected calculation of the uncertainty level of the activity data and emission factors in 2021 were determined.

In the sub-category of domestic air-conditioning systems, the main uncertainty factors were:

- complexity of statistical data samples for identification of the commodity-product range and establishing import volumes of stationary air conditioning systems with HFC-containing refrigerants;
- complexity of identification of equipment for domestic, industrial, and semi-industrial air-conditioning in analysis of customs statistics, in particular for those manufacturers and trade marks where there is a diversified range of commodities and consumer equipment;
- possible inaccuracies in determination of the average lifetime of equipment for stationary air conditioning in Ukraine with HFC refrigerants, taking into account the different conditions of operation of the equipment.

The calculated uncertainty of activity data in 2021 was 20.8% in the category of domestic air-conditioning systems, of the default coefficients used - 14.14%, the combined uncertainty of GHG emission estimation is 25.15%.

The key uncertainty factors for activity data in the sub-category of semi-industrial and industrial air conditioners were:

- lack of official statistical reporting on production in Ukraine of semi-industrial and industrial air-conditioning systems;
- complexity of identification of industrial and semi-industrial air-conditioning equipment, the absence of unambiguous criteria for grading of such equipment;
- high levels of individualization of technical and consumer parameters of semi-industrial, and especially industrial SACs (selection of the refrigerant type, the period of filling the

system with refrigerant, high conditionality of typical emission factors at system filling and operation, etc.);

- difficulty of establishing the average operation period of the equipment in Ukraine.

The calculated uncertainty level of activity data in the sub-category in 2021 was 44.44%, of the default coefficients used - 29.93%, the combined uncertainty of GHG emission estimation is 51.96%. The high uncertainty level of the activity data is due to complexity of analyzing foreign trade statistics, which in the reporting year are often fragmented and do not allow for an accurate count of the number of air conditioning equipment imported to Ukraine.

4.7.1.3.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.7.1.3.5. Category-specific recalculations

In this category, no recalculations were made.

4.7.1.3.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.7.2 Foam Blowing Agents (CRF category 2.F.2).

4.7.2.1 Category description

Disaggregation of activity and GHG emission data in this category was based on production and imports of all types of foam materials and products based on them where hydrofluorocarbon-based foaming agents are used. These subcategories are:

- one-component polyurethane foams (OPF);
- panels and sandwich panels made of rigid polyurethane foams (RPUF);
- rigid polyurethane foam (PUF insulation by spraying, pouring, injection);
- extruded polystyrene foam (XPS).

In 2021, hydrofluorocarbons HFC-134a, HFC-245fa, HFC-365mfc, HFC-227ea, HFC-152a were used as blowing agents for production and in composition of imports of foam materials (products).

In the subcategory of one-component polyurethane foams in 2021 one producer operated, which used as a blowing agent a mixture of propane-butane, Freons R-22 and R-406. Imports of OPFs containing HFCs were minimal.

In the subcategory of PUF panels and sandwich panels in 2021, out of the 15 producers operating 10 companies used as blowing agents $CO_2(H_2O)$, pentane, HCFC 141b-based polyols. Imports of PUF panels and sandwich panels comprising HFC as the blowing agent were estimated on the basis of an analytical sample of customs statistics data and expert estimates.

In the subcategory of rigid insulation PUF produced by spraying, pouring, injection, in Ukraine there are around 160 enterprises in various fields of specialization that carry out technological and production work forming rigid polyurethane foam insulation for various purposes: for warehouse and industrial premises, electrical products, refrigeration equipment, automotive industry, and others.

In the subcategory of XPS, in 2021 2 manufacturers of XPS plates operated and used as the blowing agent carbon dioxide alone or as a mixture with ethyl alcohol, and a mixture of chlorofluorocarbons and hydrochlorofluorocarbons (R22, R-142, R-406) with isobutane R-600A.

Formation of activity data in the category of foamed materials (products) production was based on data obtained directly from manufacturers, as well as from other representative sources.

They included data on the amounts of hydrofluorocarbons use for production of foamed materials (products), trademarks and formulations of HFC-containing polyols, etc. Table 4.34 summarizes results of GHG inventory in production and use of foamed HFC-containing materials.

Table 4.34 Basic data on results of GHG inventory in production and use of foamed HFC-containing materials in 2021.

Category code	2.F.2								
Type of foamed materials (products)	OPF	Panels and sandwich panels made of PUF		RPUF insulation by spraying, pouring, injection				Extruded foamed polystyrene	
Gas	HFC-134a	HFC-134a	HFC-245fa	HFC-134a	HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
Activity data									
HFC amount used in production of foamed materials (products), t	0.0	23.5	0.0	69.59	0.0	0.0	18.82	0.0	0.0
HFC amount contained in exports of foamed materials (products), t	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HFC amount contained in imports of foamed materials (products), t	51.47	1.16	1	0.0	0.0	0.0	0.0	0.472	129.0
HFC stock as of the end of 2020, t	0.0	28.76	19.4	433.46	135.42	138.54	105.52	146.9	1612.3
Category characteristics and estimated factors									
Key category	No	No	No	No	No	No	No	No	No
Detail level (Tier)	2a	2a	2a	2a	2a	2a	2a	2a	2a
Method for determination of the emission factor	D	D	D	D	D	D	D	D	D
Emission factor for the first year,%	100.0	12.5	12.5	25.0	25.0	25.0	25.0	40.0	40.0
Emission factor from the stock,%	0.0	0.5	0.5	1.5	1.5	1.5	1.5	3.0	25.0
Average service life of the material (product) during operation, years	1	50	50	50	50	50	50	50	50
GHG emissions									
HFCs emissions									
in manufacture of foamed materials (products), t	0.0	2.94	0.0	17.4	0.0	0.0	4.71	0.0	0.0
in operation of foamed materials (products), t	51.47	0.144	0.097	6.502	2.031	2.08	1.58	4.407	403.8
Emissions of HFCs in category, total, t	51.47	3.08	0.097	23.9	2.031	2.08	6.29	4.407	403.08
GWP, t CO_{2-eq} /t	1430	1430	1030	1430	1030	794	3220	1430	124
GHG emissions, kt of CO_{2-eq}	73.61	4.4	0.099	34.18	2.092	1.65	20.25	6.302	49.98
Change in emissions compared to the previous year (increase/decrease rate),%	16.7	15.81		15.695				7.004	

Category code	2.F.2								
Type of foamed materials (products)	OPF	Panels and sandwich panels made of PUF		RPUF insulation by spraying, pouring, injection				Extruded foamed polystyrene	
Gas	HFC-134a	HFC-134a	HFC-245fa	HFC-134a	HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
Emissions, % of the total direct action GHG emissions in the sector	0.13	0.008		0.1				0.096	
Uncertainty estimation									
Uncertainty of activity data, %	22.07	28.35		29.15				11.70	
Uncertainty of the emission factor, %	7.07	36.05		32.02				20.0	
Uncertainty of the emission estimation, %	22.63	45.86		43.30				23.17	

4.7.2.2. Methodological issues

Estimation of hydrofluorocarbon emissions in the category of foam blowing materials was performed by subcategories using 2a method. All the subcategories, except for one-component polyurethane foams, are closed pore foams.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

Activity data were obtained or calculated from the raw data of enterprises-producers and an data of Index of industrial production 2021 obtained from SSSU for production of foams in 2021 as well as from State Custom Service of Ukraine on import of HFC-152a for Extruded foamed polystyrene in 2021.

To estimate the volume of HFC imports in composition of polyols, representative data on the composition of polyol blends of the set trademarks were used.

To calculate the scope of HFC imports as part of foamed materials (products), a variety of estimation factors were used depending on characteristics of each sub-category.

In some foamed material sub-categories, amounts - usually minor - of imports with an unidentified foam blowing agent were detected. The concession method was applied to them based on expert judgment regarding the proportion of foam materials that could contain hydrofluorocarbons as blowing agents.

For each sub-category of foamed materials, default emission factors for production and operation were applied, as well as the average data on the lifetime of the materials (products).

The calculation of the HFC-152a emissions from its use in Extruded foamed polystyrene production was performed for the first time. The default emission factors for production and operation, as well as the average data on the lifetime of the materials (products) were applied for HFC-152a emission calculation in accordance with 2006 IPCC Guidelines [1]. The calculations of HFC-152a emissions from Extruded foamed polystyrene production were performed only for 2011- 2021 according to the data of HFC-152a import provided by State Custom Service of Ukraine. In accordance with data obtained from State Custom Service of Ukraine the import of HFC-152a for Extruded foamed polystyrene production for 1990 – 2010 was absent.

4.7.2.3. Uncertainties and time-series consistency

The uncertainty levels of the activity data and emission factors in the foamed materials category and its subcategories were determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factors of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13].

For each subcategory of foamed materials, the specific uncertainty factors that affected calculation of the uncertainty level of the activity data and emission factors, as well as the total emission estimation uncertainly levels, in 2021 were determined and applied.

The general uncertainty factors in almost all subcategories of foamed materials (products) were: difficulty of identifying foam blowing agents in general and HFC-based ones, in particular in imports of polyols, foam blowing materials (products).

The range of the activity data uncertainty levels in the category of foamed materials in the context of individual subcategories in 2021 was from 11.70 to 29.15%; of default HFC emission factors - from 7.07 to 36.05%, of emission estimates - from 22.63 to 45.86%.

4.7.2.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use. An expert judgement from a group of experts of SE "Cherkasky NIITEKHIM" was obtained for this category.

4.7.2.5. Category-specific recalculations

In 2021 in this category recalculation of HFC emissions in 2011 - 2020 for Foam Blowing Agents was made due to accounting of the HFC-152a emissions that were calculated for the first time in accordance with 2006 IPCC Guidelines [1] and data obtained from State Custom Service of Ukraine.

Table 4.35 Recalculation of HFC emissions in foam blowing agents in 2011-2020.

2.F.2 Foam Blowing Agents	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
HFCs										
Emissions (before recalculating), kt	97.15	69.12	77.60	72.50	61.70	73.72	82.52	97.17	106.68	123.74
Emissions (after recalculating), kt	100.32	72.66	88.07	93.76	85.23	102.70	115.84	134.34	147.14	169.84
Emission difference,%	3.27	5.12	13.49	29.32	38.13	39.31	40.37	38.25	37.93	37.26

4.7.2.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.7.3 Fire protection (CRF category 2.F.3)

4.7.3.1 Category description

In the fire extinguisher category, use of hydrofluorocarbons as extinguishing agents in gas (flooding) extinguishing systems was considered.

Out of the list of hydrofluorocarbons permitted for use in Ukraine as an extinguishing agent in gas fire-extinguishing system, in 2021 only HFC-125 and HFC-227ea were applied.

Manufacture of fire-fighting equipment using HFCs as a fire extinguishing agent in 2021 was carried out only by specialized enterprises.

Formation of activity data in the fire extinguisher category was based on data obtained directly from manufacturers of gas extinguishing systems, namely:

- information on the amount of use of fluorine gases (by type) for production of gas fire fighting modules (GFFM);
- information on the amount of filling with fluorine gases fire fighting modules of various sizes derived from technical specifications.

Documented activity data were provided by producers of GFFMs.

Enterprise data were used to determine the HFC stock and emissions from operation of the existing fleet of gas extinguishing systems in Ukraine.

The object of the sample was charged gas extinguishing units containing HFC-125 and HFC-227ea. Table 4.36 summarizes results of GHG emission inventory in production and operation of gas extinguishing systems using HFCs.

Table 4.36. Basic data on results of GHG inventory in production and operation of gas fire fighting modules (GFFMs) in 2021.

Category code	**2.F.3**	
Type of equipment	**Gas fire fighting modules (GFFMs)**	
Extinguishing agent (gas)	**HFC-125**	**HFC-227ea**
Activity data		
Use of HFCs in equipment production, t	22.28	21.1
Amount of HFC in exported equipment, t	-	-
Amount of HFC in imported equipment, t	9.61	9.33
HFC stock in the operated equipment as of the end of 2020, t	202.06	192.94
HFC stock in the operated equipment as of the end of 2021, t	225.87	215.66
Category characteristics and estimated factors		
Key category	No	No
Detail level (Tier)	1a	1a
Method for determination of the emission factor	D	D
Emission factor at operation of the equipment,%	4	4
Average life of equipment	15	15
GHG emissions		
HFCs emissions		
at operation of the equipment, t	9.03	8.63
at liquidation of the equipment, t	0.0	0.0
Emissions of HFCs in category, total, t	9.03	8.63
GWP, t CO_{2-eq} /t	3500	3220
GHG emissions, kt of CO_{2-eq}	31.62	27.78
Change in emissions compared to the previous year (increase/decrease rate), %	11.78	11.78
Emissions, % of the total direct action GHG emissions in the sector	0.054	0.048
Uncertainty level estimation		
Uncertainty of activity data, %	16.70	
Uncertainty of the emission factor, %	not performed	
Uncertainty of the emission estimation, %	16.70	

4.7.3.2 Methodological issues

Estimation of hydrofluorocarbon emissions in this category was performed for production and operation of gas fire extinguishing systems using 1a level method.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

Activity data in 2021 in the category of fire fighting systems were obtained or calculated on the basis of input data:

- on volumes of equipment production and the content of the fire-extinguishing agent received from fire-fighting equipment manufacturing enterprises and to the statistics of imports of the State Custom Service of Ukraine;
- on HFC volumes imported to replenish available GPPSs with fire extinguishing agents.

The sampling object was a gas fire extinguishing unit (production, export, import) charged with fire extinguishing hydrofluorocarbon agents (HFC-125 and HFC-227ea).

4.7.3.3 Uncertainties and time-series consistency

The uncertainty level of the activity data and emission factors in the fire extinguisher category was determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factor of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13], based on the specific characteristics of input and calculated data formation in 2021.

For the category of gas fire extinguishing, specific of activity and emission data uncertainty factors were established, which were included into the formula for calculating the combined uncertainty level.

The key causes of activity data uncertainty assessment the gas fire extinguisher category were:

- complexity of obtaining data on the amount of HFC use for maintenance of existing gas extinguishing systems (the current period);
- complexity of identifying and calculating the data on the volume of HFC imports into Ukraine (by type) as part of gas fire extinguishing systems.

Activity data in the gas fire extinguisher category were provided by the manufacturing enterprises.

When calculating emissions in this category, the default emission factors recommended by the IPCC were used.

The calculated total uncertainty of activity data and emission estimates in the category of gas fire extinguishers in 2021 was 16.70%.

4.7.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.7.3.5 Category-specific recalculations

In 2021 in this category recalculation of HFC emissions in 2018 - 2020 for Fire protection was made due to adjustment of the data of the use of HFCs in equipment production in accordance with data obtained from enterprises.

Table 4.37 Recalculation of HFC emissions in foam blowing agents in 2018-2020.

2.F.3 Fire protection	**2018**	**2019**	**2020**
HFCs			
Emissions (before recalculating), kt	39.68	43.31	47.03
Emissions (after recalculating), kt	41.78	48.00	53.14
Emission difference,%	5.307	10.823	12.989

4.7.3.6 Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.7.4 Aerosols (CRF category 2.F.4)

4.7.4.1 Category description

In 2021 in Ukraine use of hydrofluorocarbons (HFC-134a) in this category was observed exclusively in production and consumption of medical aerosols for inhalation and for other purposes (metered-dose aerosol inhalation, aerosols for external use, etc.).

In Ukraine, three producers of aerosols for medical purposes operated in 2021, which used HFC-134a in production as a propellant gas. Ukraine only imported inhalation and other aerosol medications containing HFC-134a as the propellant gas. HFC-152a was not imported to Ukraine.

Formation of activity data for production of aerosol formulations for medical purposes was based on data obtained directly from the manufacturers. They included data on production volumes of aerosols for medical purposes containing HFC-134a (in aerosol bottles and in tons by product names), HFC volumes used in manufacture of medical aerosols, the content of the propellant gas. Documented activity data were obtained in this category from all manufacturers.

In 2021, only HFC-134a was used in production and importation of aerosol formulations for medical purposes, HFC-227ea was not included into the composition of the imported aerosols. Table 4.38 summarizes results of GHG inventory in production and use of HFC-containing aerosols.

Table 4.38 Basic data on results of GHG inventory in production and use of HFC-containing aerosols in 2021.

Category code	**2.F.4**		
Category	**Aerosols**		
	Aerosols for medical purposes	Aerosols for industrial purposes	
Gas	**HFC-134a**	**HFC-134a**	**HFC-152a**
Activity data			
HFC amount used in production of aerosols, t	21.25	-	-
HFC amount contained in exports of aerosols, t	3.47	-	-
HFC amount contained in aerosol supplies for the domestic market, t	-	-	-
HFC amount contained in imports of aerosols, t	53.16	-	-
Net consumption of HFCs contained in aerosols, t	71.06	-	-
Category characteristics and estimated factors			
Key category	No	-	-
Detail level (Tier)	2a	-	-
Method for determination of the emission factor	D	-	-
Emission factor for the first year,%	50	-	-
Emission factor from the stock,%	50	-	-
Average service life of the material (product) during operation, years	2	-	-
GHG emissions			
HFCs emissions			
at aerosol use, t	83.96	-	-
Emissions of HFCs in category, total, t	83.96	-	-
GWP, t CO_{2-eq} /t	1430	-	-
GHG emissions, kt of CO_{2-eq}	120.07	-	-
Change in emissions compared to the previous year (increase/decrease rate),%	6.74	-	-
Emissions, % of the total direct action GHG emissions in the sector	0.21	-	-
Uncertainty estimation			
Uncertainty of activity data, %	6.70	Not determined	
Uncertainty of the emission factor, %	5.39		
Uncertainty of the emission estimation, %	8.60		

4.7.4.2 Methodological issues

Estimation of emissions of hydrofluorocarbons in the category of aerosols was carried out using 2a level method.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

The calculation of the volume of production, exports, and imports of aerosols for medical purposes included counting of the number of produced, exported, and imported products by trade names of the drugs in vials and in tons (gross weight).

Estimation of GHG emissions in this category was based on calculation of net consumption of HFCs in composition of aerosols in the current period based on the default emission factor for the propellant gas of 50% during the first year, and the HFC stock as of the beginning of the year (50% from the previous year's indicator).

In 2021, the decrease dynamics in HFC emissions from the category of aerosol products for medical purposes in Ukraine resumed. This trend is likely to be situational and is due, in addition to the purchasing power, to the administration of the domestic pharmaceutical market.

4.7.4.3. Uncertainties and time-series consistency

The uncertainty levels of the activity data and emission factors in the aerosol category were determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factors of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13].

The key uncertainty factors in this category in 2021 were:

- a certain complexity of calculation and possible discrepancies in analytical data processing when converting the quantitative volume of imports of aerosol formulations for medical purposes into the identical measurement units (spray bottles), if another unit is specified in the customs declaration (weight, value);
- unclear identification of data on the composition of aerosol formulations for medical purposes for individual commodity items and the weight fraction of the propellant gas per unit of accounting (spray bottle) contained in the drug use documentation.

Obtaining comprehensive input data from producing companies for 2021 on the composition of aerosol formulations for medical purposes ensured the lowest level of uncertainties in this category.

The total uncertainty of activity data in the aerosol category was 6.70% in 2021, the uncertainty of the default HFC emission factor for this category was 5.39%. The total uncertainty of emission data in the aerosol category was 8.60%.

4.7.4.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.7.4.5. Category-specific recalculations

In this category, no recalculations were made.

4.7.4.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.7.5 Solvents (CRF category 2.F.5)

In Ukraine, homogeneous solvents and/or mixed (heterogeneous) solvents using HFCs as the primary solvent or blend solvent were not produced in 2021. Analysis of the statistics for 2021 confirmed that solvents were not imported to Ukraine. Therefore, estimation of GHG emissions in this category was not performed.

4.7.6 Other Applications of Substitutes for Ozone-Depleting Substances(CRF category 2.F.6)

As a result of the analysis of imports and domestic sales of HFCs and sulfur hexafluoride in 2020, no data on use of these gases used in other industries were obtained..

Therefore, estimation of GHG emissions in this category was not performed.

4.8 Other Product Manufacture and Use (CRF category 2.G)

Emissions in this category are estimating from sulphur hexafluoride (SF_6) from the manufacture and use of electrical equipment and a number of other products and emissions of nitrous oxide (N_2O) use for medical purposes. The main SF_6 emissions occurs only from its use in gas-insulated equipment and N_2O from its use in surgical operations. The subcategories in this category are not the key sources of emissions. The activity data collection, methodological issues as well as QA/QC procedures etc. by the categories included in this category are shown by each subcategory in relevant chapters.

4.8.1 Electrical Equipment (2.G.1 CRF)

4.8.1.1 Category description

Sulphur hexafluoride ($SF_{6)}$ is used for transmission and distribution of electric power in switching systems and high voltage equipment (52-380 kV), as well as in medium voltage systems (10-52 kV).

Ukraine has no own production of sulfur hexafluoride (SHF/$SF_{6)}$. It is imported to Ukraine in volumes necessary for production of own gas-insulated equipment, annual assembly and installation of new equipment, as well as for repair and normal operation of the existing fleet of gas-insulated equipment.

A bulk of imported sulfur hexafluoride (over 65%) is used for repair and operation of the available fleet of gas-insulated equipment at electrical substations of the Ministry of Energy and Mines, the Ministry of Infrastructure, industrial enterprises in other sectors. Around 20% of SF_6 imported to Ukraine was used in production of gas-insulated equipment: transformers and gas-insulated switchgears. Ukraine has no own production of gas-insulated circuit breakers. Industrial consumption SF_6 is mainly concentrated in the two segments: production of complete gas-insulated switchgears, production of complete gas-insulated transformer substations, and production of gas-insulated current and voltage transformers. Table 4.39 summarizes results of GHG inventory in production and operation of gas-insulated equipment.

Table 4.39 Basic data on results of GHG inventory in production and operation of gas-insulated equipment in 2021.

Category code	**2.G.1**
Category (type of equipment)	**Gas-insulated equipment**
Gas	**Sulfur hexafluoride**
Activity data	
The amount of SF_6 imported into Ukraine in 2021, t	27.21
Number SF_6 used in production of gas-insulated equipment (filling stage), t	1.007
Amount of SF_6 in exported gas-insulated equipment, t	-
Amount of SF_6 in imported gas-insulated equipment, t	26.69
Amount of SF_6 in installed gas-insulated equipment (nameplate capacity of new equipment put into operation in 2021), t	50.95
Amount of SF_6 in operated gas-insulated equipment (nameplate capacity of operated equipment as of the end of 2020), t	377.15
Amount of SF_6 in operated gas-insulated equipment (nameplate capacity of operated equipment as of the end of 2021), t	426.21
Category characteristics and estimated factors	

Key category	No
Detail level (Tier)	2a, 3a
Method for determination of the emission factor	D
SF_6 emission factor in production of gas-insulated equipment (the filling stage),%	0.5
The emission factor at assemblage (installation) of gas-insulated equipment,%	0.0
Emission factor at operation of gas-insulated equipment,%	0.5
Average lifetime of the equipment, years	30-40
GHG emissions	
SF_6 emissions	
at manufacture of the equipment (the filling stage), t	0.005
at installation (assembly) of gas-insulated equipment, t	0.011
at operation of gas-insulated equipment, t	2.13
SF_6 emissions in the gas-insulated equipment category, total, t	2.15
GWP, t CO_2e/t	22800
GHG emissions, kt of CO_2e	48.94
Growth/reductionof emissions compared to the previous year (+/-),%	11.6
Emissions, % of the total direct action GHG emissions in the sector	0.084
Uncertainty level estimation	
Uncertainty of activity data, %	34.104
Uncertainty of the emission factor, %	18.0
Uncertainty of the emission estimation, %	38.56

4.8.1.2 Methodological issues

Estimation of sulfur hexafluoride emissions in this category was conducted at production and operation of gas-insulated equipment with Tier 2a assessment method and partially the mass-balance Tier 3a method, based on the need.

As a methodological basis, "The methodology of calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level (State Enterprise "Cherkasky NIITEKHIM", 2012) [13] was used, which is based on 2006 IPCC Guidelines [1] and 2000 IPCC Guidelines [4].

The activity data in 2021 in this category were obtained from manufacturers of high-voltage gas-insulated switchgears, 0.4-110 kV gas-insulated transformers, and gas-insulated equipment using companies and using the method of substitution due to the lack of concretely data for 2021 in accordance with data obtained from State Custom Service of Ukraine. Data on actual volumes of sulfur hexafluoride used in production of gas-insulated equipment in 2021 were also obtained from the enterprises-producers with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of volumes of sulfur hexafluoride in 2014 - 2021.

During the inventory in the subcategory, the SF_6 emission factor (0.5%) in production of gas-insulated equipment was used, which was established on the basis of factual data obtained from manufacturers using Tier 3a method (the mass-balance method).

In accordance with the "Methodology for calculating emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) at the national level" (State Enterprise "Cherkasky NIITEKHIM", Cherkasy, 2012) [13], the SF_6 emission factor in operation was established on the basis of data from gas-insulated equipment producing and supplying enterprises.

For complete gas-insulated switchgear, as a rule, the zero SF_6 emission factor during operation is applied (for the exception of emergency equipment repairs), or a factor not more than 0.1%.

For some imported second-generation gas-insulated equipment (current and voltage transformers), the SF_6 emission factor is set at less than 0.1%.

To calculate SF_6 emissions during operation of gas-insulated equipment in this category in 2021, the average factor of 0.5% was applied.

4.8.1.3 Uncertainties and time-series consistency

The uncertainty level of the activity data and emission factors in the gas-insulated equipment category was determined based on the Methods of determination and results of calculations for estimating the uncertainty of activity data and emission factors of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) in the major categories (SE "Cherkasky NIITEKHIM", Cherkasy 2012) [13], based on the specific characteristics of input and calculated data formation in 2016.

Activity data in the gas-insulated equipment category were submitted by the producing companies, consumer companies, and importers of the equipment for the domestic market.

In 2021, the key activity data uncertainty factors in the category of gas-insulated electrical equipment were:

- the difficulty of obtaining comprehensive data on availability of the gas-insulated element with SF_6 in gas-insulated electrical equipment imported to Ukraine (for individual production companies);
- possible partial identification of the consumer range and data collected from enterprises consuming gas-insulated electrical equipment;
- possible inaccuracies in calculation of the nameplate capacity of newly installed and operated gas-insulated equipment.

The calculated activity data uncertainty level in the category of gas-insulated equipment amounted to 34.104% for the period indicated.

The uncertainty of the default emission factors in the category of gas-insulated equipment in 2021 was 18%.

The overall uncertainty of sulfur hexafluoride emission estimation was 38.56% in 2021.

4.8.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in SF_6 use.

4.8.1.5 Category-specific recalculations

In 2021 in this category recalculation of SF_6 emissions was made due to adjustment of the data of the amounts of SF6 in installed gas-insulated equipment for 2019 - 2020 according to the data obtained from enterprises.

Table 4.40 Recalculation of SF_6 emissions in gas-insulated equipment in 2019-2020.

2.G.1 Electrical Equipment	**2019**	**2020**
SF_6		
Emissions (before recalculating), kt	38.67	43.16
Emissions (after recalculating), kt	38.79	43.35
Emission difference,%	0.30	0.44

4.8.1.6 Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.8.2 SF_6 and PFCs from Other Product Uses (CRF category 2.G.2)

In accordance with the scientific-research works: by the Ukrainian Research Institute of Medicine and Transport of the Ministry of Health of Ukraine "Development of methods of estimation and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride"[7] and by Cherkasy NIITEKHIM" - "Development of methods of estimation and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride" [13] as well as from data obtained from State Custom Service of Ukraine there is no SF_6 and PFCs from other product uses in Ukraine, therefore emissions in this category are not estimated.

4.8.3 N_2O from Product Uses (2.G.3 CRF)

4.8.3.2.1 Category description

In this category, nitrous oxide emissions from its use for medical purposes (anesthesia) are estimated. Nitrous oxide emissions in 2021 amounted to 0.351 kt.

Medical nitrous oxide at ambient temperature and atmospheric pressure is a gas. In production, transportation, and up to the direct application in hospitals, it is stored in the liquefied form in bombs under high pressure. The bombs are 10 liter seamless hermetically sealed containers of carbon steel in accordance with GOST 949-73 with the base material content of 6.2 kg. All nitrous oxide used in medical institutions fully gets into the air, since after its use as an inhalation anesthetic the gas is exhaled by the patient (elimination - 100%) with no utilization, and 100% of its volume releases into the environment.

4.8.3.2 Methodological issues

In this inventory, for the first time in the time series of 1990-2021, estimation of nitrous oxide emissions from its use for medical purposes is done under the algorithm developed by the State Enterprise "Ukrainian Research Institute of Transport Medicine of the Ministry of Health of Ukraine" and described in the scientific-research work "Development of methodological recommendations on definition of indicators of nitrous oxide use for medical purposes" [18], with using national emission factors.

In accordance with the algorithm, annual nitrous oxide emissions from its use for medical purposes are determined according to equation:

$$Q(t) = XO \cdot IA \cdot IA_{N_2O} \cdot N \, , \qquad (2)$$

where: $Q(t)$ - the volume of nitrous oxide emissions from its use for medical purposes in year t, kt;

XO - the number of surgeries conducted, surgeries/year;

IA - the share of inhalation surgeries in the structure of the total number of surgical procedures performed;

IA_{N_2O} - the proportion of nitrous oxide use as an anesthetic in the structure of inhalation surgeries made;

N - the amount of nitrous oxide used per inhalation surgery with its application, kg.

The data on surgical operations performed in Ukraine in the period of 1990 - 2021 were analyzed and systematized in the expert estimation[4] in accordance with data obtained from the Ministry of Health of Ukraine with using data from official statistic with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of number of surgical operations in 2014 - 2021. The detailed information is presented in Table 4.41 below. In general, the number of surgical operations has gradually decreased from 4280.605 thousand in 1990 to 2960.356 thousand in 2020, as well as in 2021 – 3086.921 thousand. This trend from 1990 to 2021 is due to a number of reasons: an increase in the general morbidity rate in the population until 2013, the growing number of patients who require surgical operations, the number of detected tumors, diseases of the blood circulatory system and the urinary tract, as well as introduction into the surgical practice of new technologies in line with an increase in the scope of planned surgical care and, accordingly, a decrease for these reasons from 2014 to 2021.

The share of inhalation surgeries (IA). The value of the IA factor for the time-series of 1990-2021 was calculated in the expert estimation[1], according to which this factor gradually increased from

[4] A. Fedoruk, MD, Professor of Surgery and Urology Department, Bukovysky State Medical University, deputy chief physician at the medical unit of Chernivtsi city hospital.

0.15 in 1990 and reached the value of 0.51 in 2021, which is displayed in table 4.41 below. This trend is typical for the majority of countries in the world and was supported by improvement of the material and technical base of medical and preventive treatment facilities of Ukraine: only in the last few years Ukraine received and distributed more than 800 anesthesia and respiratory devices, which allows for inhalation anesthesia.

The proportion of nitrous oxide use as an anesthetic (IA_{N_2O}). The value of the IA_{N_2O} factor for the time-series of 1990-2021 was calculated in the expert estimation[1], according to which this factor gradually increased from 0.100 in 1990 and reached the value of 0.279 in 2021, which is displayed in table 4.41. This trend is due to the relatively low cost of using nitrous oxide as an anesthetic.

The amount of nitrous oxide used per inhalation surgery (N). In the scientific research work [18], it was found that the average weight of nitrous oxide used per inhalation surgery is 0.8 kg. The value of the factor is based on the analysis of nitrous oxide use in 81 health facilities of Ukraine.

Table 4.41. Use of nitrous oxide for medical purposes in Ukraine, 1990 - 2021.

Year	The total number of surgical operations (XO), thousand	The share of inhalation anesthesia (IA)	The proportion of inhalation anesthesia using N_2O (IA_{N2O})
1990	4280.605	0.15	0.100
1991	4395.58	0.15	0.100
1992	4799.39	0.15	0.100
1993	4768.744	0.15	0.100
1994	4709.829	0.15	0.100
1995	4608.056	0.15	0.100
1996	4555.423	0.15	0.100
1997	4379.378	0.15	0.100
1998	4488.427	0.15	0.100
1999	4569.398	0.15	0.100
2000	4905.764	0.15	0.150
2001	4840.657	0.15	0.150
2002	4860.692	0.15	0.150
2003	4973.975	0.15	0.150
2004	5026.678	0.15	0.150
2005	5044.089	0.15	0.150
2006	5053.335	0.18	0.263
2007	5112.678	0.18	0.263
2008	5481.381	0.18	0.263
2009	4915.107	0.51	0.279
2010	4951.215	0.51	0.279
2011	4934.49	0.51	0.279
2012	4907.676	0.51	0.279
2013	4894.296	0.51	0.279
2014	4277.608	0.51	0.279
2015	4300.679	0.51	0.279
2016	4280.791	0.51	0.279
2017	4256.299	0.51	0.279
2018	4171.564	0.51	0.279
2019	3862.909	0.51	0.279
2020	2960.356	0.51	0.279
2021	3086.921	0.51	0.279

4.8.3.3 Uncertainties and time-series

The range of activity data and emission factor uncertainty estimates in the category Other Applications is displayed in table 4.42. and was determined in accordance with 2006 IPCC Guidelines [1].

Table 4.42. The range of uncertainty estimates

Parameter	Estimated uncertainty	
	"-"	"+"
Activity data		
The number of surgical operations, XO	5	5
Completeness of the sampling and data processing time series	7.8	7.8
The balance of domestic consumption of nitrous oxide	10	10
Uncertainty of activity data	13.63	13.63
Emission factors		
The share of inhalation surgeries, IA	10	10
The proportion of nitrous oxide use as an anesthetic, IA_{N2O}	26.42	26.42
Uncertainty of nitrous oxide emission factors	28.25	28.25
Standard uncertainty of N_2O emissions	31.37	31.37

4.8.3.4 Category-specific QA/QC procedures

For estimation of emissions in the category, the following quality control procedures were applied:

- comparison of activity data from different sources;
- comparison of emission along the time-series and analysis of activity data trends;

4.8.3.5 Category-specific recalculations

In 2021 in this category recalculation of N_2O emissions from Other product uses was made due to adjustment of the data of number of surgical operations in 2020 according to the data obtained from enterprise.

Table 4.43 Recalculation of emissions from N_2O in Other product uses in 2020.

2.G.3 N_2O from Product Uses	**2020**
N_2O	
Emissions (before recalculating), kt	0.3389
Emissions (after recalculating), kt	0.3370
Emission difference,%	-0.57

4.8.3.6 Category-specific planned improvements

In this category, no improvements are planned.

4.9 Other (CRF category 2.H)

Emissions in this category are estimating from pulp, paper, food and beverages production. In this categories only the precursors and SO_2 emissions occurs. The subcategories in this category are not the key sources of emissions. The activity data collection, methodological issues as well as QA/QC procedures etc. by the categories included in this category are shown by each subcategory in relevant chapters.

4.9.1 Pulp and Paper Production (CRF category 2.H.1)

4.9.1.1 Category description

Pulp and paper industry produces various types of paper and cardboard manufacturing technology of which consists in obtaining paper mass from fibrous material - pulp. The raw material for paper pulp is wood. In pulp and paper production emissions of NMVOCs, NO_x, CO, and SO_2 occurs. Since 2011, pulp has not been produced in Ukraine. Table 4.44 shows the basic data on the results of GHG inventory in paper production.

Table 4.44. The basic data on the results of GHG inventory in paper and pulp production in 2021.

Category code	**2.H.1**			
Gases	NO_x	CO	NMVOC	SO_2
Emissions from production, kt	1.087	5.976	2.173	2.173
Change in emissions compared to the previous year,%	5.60			
Change in emissions compared to the baseline year,%	129.53			
Emissions, % of emissions in the sector	4.39	16.4	1.96	3.8
The key category	No			
Detail level (Tier)	1	1	1	1
Method for determination of the emission factor	D	D	D	D
Emission factor at production, t/t	0.001	0.0055	0.002	0.002

4.9.1.2 Methodological issues

Emissions of NMVOC, NO_x, CO, and SO_2 in paper manufacture were determined in accordance with 2013 EMEP/EEA recommendations [6]. Data on the amounts of paper production in Ukraine were obtained from SSSU[2]. The default GHG and SO_2 emission factors were used.

4.9.1.3 Uncertainties and time-series consistency

Since in pulp and paper production GHG emissions do not happen, the uncertainty of emission estimation results in this category was not calculated.

4.9.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied to calculation of GHG emissions from paper production.

4.9.1.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.9.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.9.2 Food and Beverages Industry (CRF category 2.H.2)

4.9.2.1 Category description

The food industry produces a wide range of products based on application of various technological processes. Food composition includes organic substances that during processing emit into the atmosphere as NMVOCs. The greatest amount of NMVOCs is emitted in production of alcoholic beverages, bakery products, edible fats, meat and fish products. Table 4.45 presents activity data, emission and NMVOC emission factors at production of food and beverages in Ukraine.

Table 4.45. NMVOC emissions in production of food and beverages in 2021.

Category code	2.H.2
Food Production, kt	11437.64
Beverage Production, 10^3 hl	20201.19
Gas	NMVOC
Emissions from products, kt	30.72
Emissions from beverages, kt	11.14
Total emissions, thousand tons	41.86
Change in emissions compared to the previous year,%	13.03
Change in emissions compared to the baseline year,%	-70.01
Emissions, % of emissions in the sector	37.66
The key category	No
Detail level (Tier)	1
Method for determination of the emission factor	D

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.17, Annex 3.1.1.

4.9.2.2 Methodological issues

Estimation of NMVOC emissions in food and beverage industries was made in accordance with the recommendations in section 2.15 of 2013 EMEP/EEA Guidelines [6] using default emission factors. NMVOC emission estimation was performed for production of bread and bakery products, flour confectionery products, fodder for animals, margarine and solid edible fats, sugar, meat, fish and poultry, spirits, wine and beer. The data used for the estimation of emissions were provided by the SSSU[2], with using data from official statistic with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [19] for adjustment of number of food and beverages in 2015 - 2020.

4.9.2.3 Uncertainties and time-series consistency

Since in food and beverages production GHG emissions do not happen, the uncertainty of NMVOC emission estimation results in this category was not calculated.

4.9.2.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of NMVOC emissions at food and beverage production.

4.9.2.5 Category-specific recalculations

In 2021 in this category recalculation of NMVOC emissions for 1990-2020 was carried out due to the adjustment of the amounts of food and beverages production according to the data obtained from SSSU [2].

Table 4.46 Recalculation of emissions from Ammonia Production in 2021.

2.H.2 Food and Beverages Industry	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
NMVOC								
Emissions (before recalculating), kt	139.55	114.92	102.04	111.27	95.90	97.60	75.26	60.17
Emissions (after recalculating), kt	128.90	110.16	99.04	108.12	93.32	94.59	73.60	58.96
Difference, %	8.26	4.32	3.03	2.92	2.77	3.18	2.25	2.06
2.H.2 Food and Beverages Industry	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Emissions (before recalculating), kt	53.63	48.21	48.26	49.70	49.59	63.12	71.75	69.10
Emissions (after recalculating), kt	52.47	51.78	48.54	52.16	50.61	63.48	70.59	67.83

Difference, %	2.21	-6.88	-0.57	-4.72	-2.01	-0.57	1.64	1.87
2.H.2 Food and Beverages Industry	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Emissions (before recalculating), kt	74.25	68.07	67.14	65.96	71.90	73.04	68.61	54.90
Emissions (after recalculating), kt	73.26	67.01	64.79	63.65	69.76	72.19	67.50	53.69
Difference, %	1.35	1.58	3.62	3.63	3.06	1.17	1.64	2.25
2.H.2 Food and Beverages Industry	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Emissions (before recalculating), kt	62.89	50.78	55.12	58.81	53.30	44.19	39.23	
Emissions (after recalculating), kt	60.14	49.66	54.17	58.18	53.28	43.34	37.03	
Difference, %	4.58	2.26	1.76	1.07	0.03	1.98	5.92	

4.9.2.6 Category-specific planned improvements

In this category, no improvements are planned.

5 AGRICULTURE (CRF SECTOR 3)

5.1 Sector Overview

The following emission source categories considered in the Agriculture sector:
− 3.A Enteric Fermentation;
− 3.B Manure Management;
− 3.C Rice Cultivation;
− 3.D Agricultural Soils;
− 3.E Prescribed Burning of Savannas;
− 3.F Field Burning of Agricultural Residues;
− 3.G Liming;
− 3.H Urea Application.

Total emissions of direct GHG (CO_2, CH_4, N_2O) in the sector and by categories are reported in Table 5.1. In categories 3.E Prescribed Burning of Savannas and 3.F Field Burning of Agricultural Residues, emissions not estimated, since the savannas ecosystem does not exist in the territory of Ukraine, and burning of crop residues in Ukraine is legally prohibited under the Code of Administrative Offenses (art. 77-1) and the Law of Ukraine On Air Protection (art. 16, 22).

Table 5.1. Changes in GHG emissions in the Agriculture sector

Category	Emissions, kt CO_2-eq.			Trend, %	
	1990	*2020*	*2021*	*by 1990*	*by 2020*
3.A Enteric Fermentation	39 311.34	7 447.05	7 047.92	-82.07	-5.36
3.B Manure Management	6 774.76	1 944.66	1 907.75	-71.84	-1.90
3.C Rice Cultivation	216.43	82.99	74.84	-65.42	-9.82
3.D Agricultural Soils	37 678.18	34 467.41	31 845.54	-0.27	17.99
3.E Prescribed Burning of Savannas *	NO	NO	NO	–	–
3.F Field Burning of Agricultural Residues **	NO	NO	NO	–	–
3.G Liming	2 592.08	131.35	176.23	-93.20	34.17
3.H Urea Application	270.14	235.51	235.60	-12.79	0.04
Total for the sector	**86 842.92**	**41 687.10**	**47 017.37**	**-45.86**	**12.79**

** – the emissions not estimated;*

*** – field burning of crop residues prohibited by the Ukrainian legislation.*

The total GHG emissions in the sector have decreased by 45.86 % compared to the base year. However, a significant growth of GHG emissions (more than 12.78%) has occurred in 2021 in comparison with previous year (Table 5.1). There are several reasons for the observed increase in emissions, but the growth of amount of applied synthetic fertilizers and annual amount of N in crop residues are the main factors.

The highest emissions in the agricultural sector of Ukraine in reported year observed in 3.D Agricultural Soils and 3.A Enteric Fermentation categories, which make up 79.92 and 14.99 % (Fig. 5.1). The next largest category is 3.B Manure Management, which accounts for 4.06 % of the emissions. Contribution of the other categories is negligible and accounts for only 1.035 %.

The key gases in the sector are methane and nitrous oxide (Fig. 5.2), which accounted for 49.55 and 47.16 % in 1990, and 17.24 and 81.88 % of the emissions in reported year, respectively.

The reduction in emissions of GHG over the period of 1990-2021 is primarily due to the decrease in the number of livestock, in the amount of fertilizer applied to soils, as well as to a change in treatment of animal manure as a result of the collapse of the Soviet Union and the ensuing economic crisis.

One of the reasons for the emissions growth in 2001-2002 by comparison with 2000 was stabilization of swine livestock due to renewed operation of some pig farms, procurement from other countries of breeding animals, and increased subsidies. In 2003, as a result of impact of natural and economic factors, the livestock of animals in household farms declined sharply. In particular, compared with the previous year, the average annual livestock of cattle decreased by 17 %, pigs – by 10 %. The determining factor for the reducing population of animals in 2003 were extreme weather conditions (extreme cold and small amount of snow), which led to deep freezing of the ground and the subsequent decrease in the yield of harvested acreage of forage crops for livestock. In general, 2003 characterized by rapid changes in sales prices for live animals, feed grain, and other fodder.

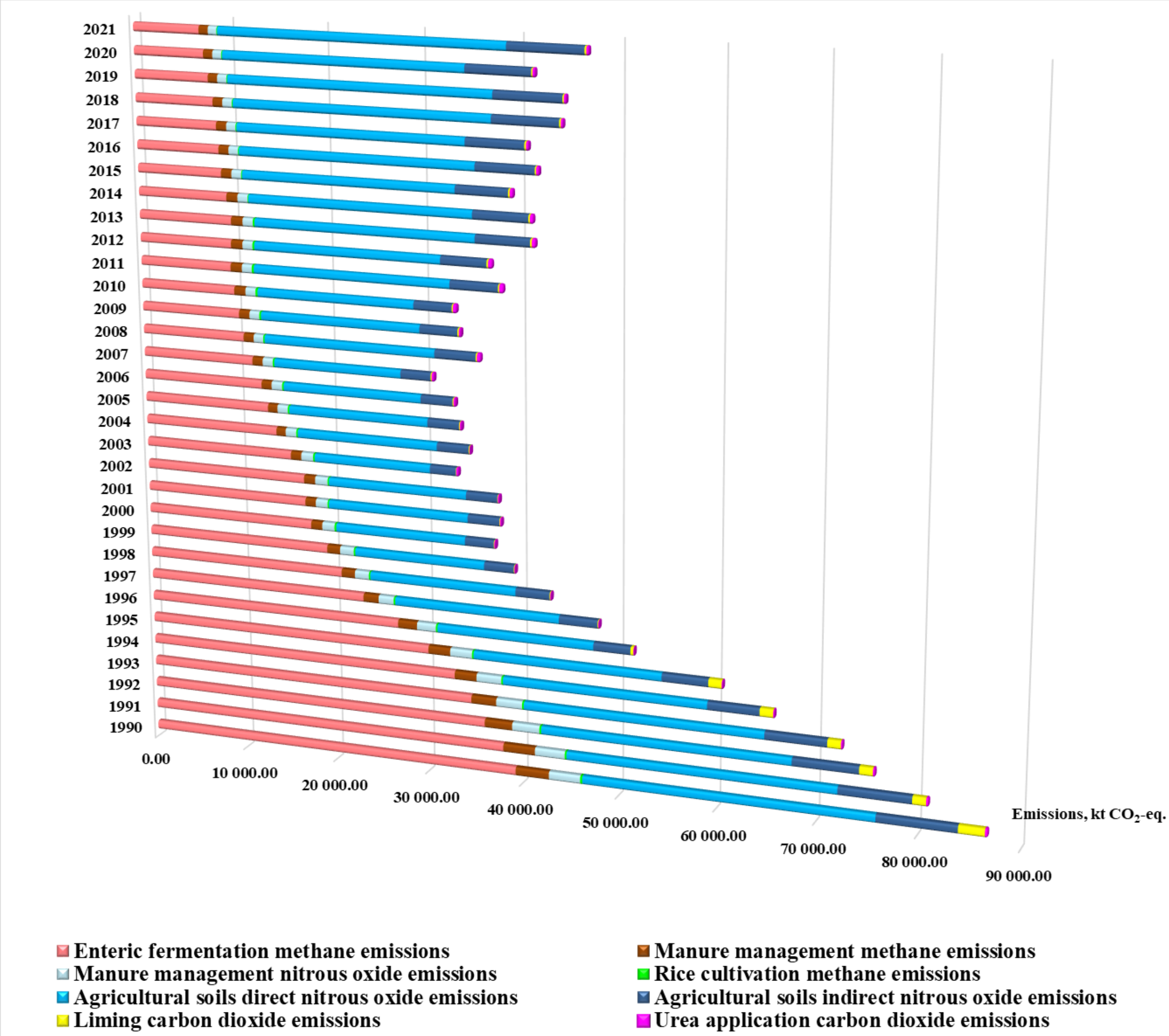


Fig. 5.1. GHG emissions by categories of the Agriculture sector, kt CO_2-eq.

The growth in direct N_2O emissions from agricultural soils in 2008 was due to an increase in the amount of crop residues going into the soil, which in turn is due to the highest in the period of Ukraine's independence gross harvest of grain and leguminous crops, which amounted to 53.3 Mt. In addition, in 2003-2021 there was an increase in the standardly introduced nitrogen fertilizers (except 2009 and 2015).

One of the main reasons of methane emissions decline in the 3.B Manure Management category in comparison with emissions in the other categories is partial replacement from liquid systems to solid storage in the manure management structure at cattle-raising enterprises. Thus, the percentage of cattle manure stored in liquid systems at agrienterprises in 1990 was 21.0 % of the total manure produced. In 2021, the corresponding proportion of manure in liquid systems was approximately 5.6 %, and the rest of the manure mostly remained on pasture/range/paddock or in solid storage. Since the potential of methane production in liquid systems is significantly higher than in case of solid storage, emission factors for the period of 1990-2021 sharply reduced. At the same time, methane emissions in the category in question in the reporting period decreased by 71.9 %.

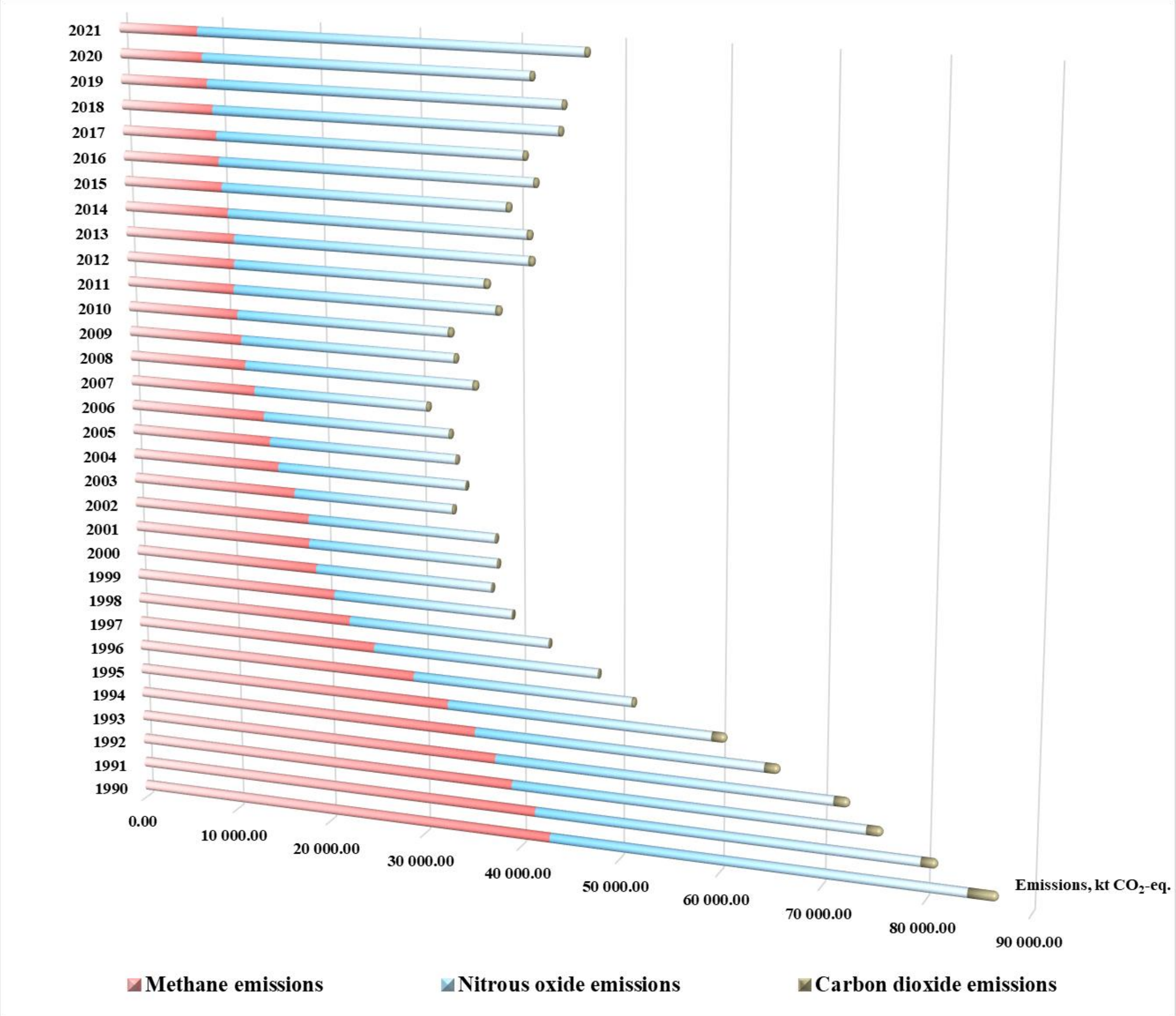


Fig. 5.2. The ratio of direct GHG emissions in the Agriculture sector, kt CO_2-eq.

5.2 Enteric Fermentation (CRF category 3.A)

5.2.1. Category description

Inventory of methane emissions from enteric fermentation in Ukraine includes such types of farm animals (Table 5.2) as cattle, sheep, swine, and other animals (goats, horses, mules and asses, rabbits, fur-bearing animals, camels and buffaloes). Ruminants (such as cattle) produce a largest part of CH_4 emissions from enteric fermentation. Emissions from poultry are not estimated, as 2006 IPCC Guidelines [1] offer no methodology for their calculation.

Table 5.2. Review of category 3.A Enteric Fermentation

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
3.A.1 Cattle	T 2	CS	CH_4	Level/Trend	1 461.46	255.81	-82.50
3.A.2 Sheep	T 2	CS			60.91	7.20	-88.17
3.A.3 Swine	T 1	D			29.53	8.99	-69.54
3.A.4 Other animals:	T 1	D			20.55	9.91	-51.79
fur-bearing animals	T 1	D			0.14	0.09	-33.23

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
rabbits	T 1	D			4.27	3.37	-21.01
camels	T 1	D			0.03	0.04	41.67
mules and asses	T 1	D			0.19	0.12	-37.04
buffaloes	T 1	D			0.05	0.01	-88.82
horses	T 1	D			13.43	3.53	-73.71
goats	T 1	D			2.45	2.75	12.12

Next data collected for GHG emissions estimating:
– the type of animals (Table 5.3, Annex 3.2.1) and their number;
– the type of the digestive system of the animals;
– feed digestibility;
– feeding situation: confined, grazing, pasture conditions;
– animal weight and their average weight gain per day;
– milk production and fat content;
– wool growth;
– animal activity and average amount of work performed per day;
– percentage of females that give birth in a year and number of offspring.

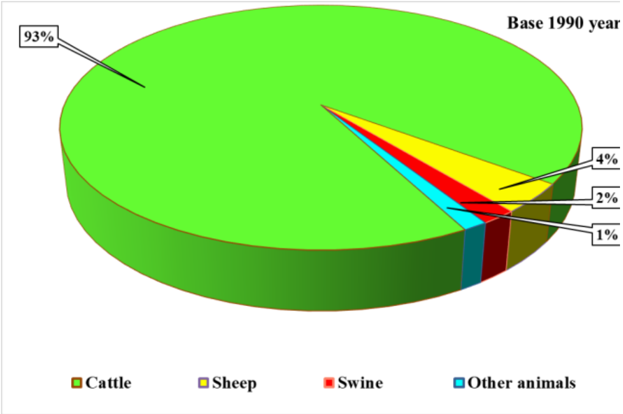
Table 5.3. Characteristics of animal species and their sources

Animal species	Data source	Reporting form	Note*
Cattle	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.1
Sheep	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.2
Swine	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.3
Fur-bearing animals	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.5
Rabbits	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.5
Buffaloes	Regional state administrations	Livestock of the animals at January 1	Annex 3.2.1.2.5
Goats	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.5
Camels	FAO	Average annual population	Annex 3.2.1.2.5
Horses	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.5
Mules and asses	FAO	Average annual population	Annex 3.2.1.2.5
Poultry	SSSU	Livestock of the animals at January 1	Annex 3.2.1.2.5

** – found in Annex 3.2 Agriculture.*

EF for cattle sex-age groups and sheep calculated in accordance with corresponding methodology (Annex 3.2.8, Tables A3.2.8.1 and A3.2.8.2). Cattle and sheep EF fluctuations mainly caused by changes of energy expenses and other several data (live weight, milk yield, wool production etc.).

Methane emissions from enteric fermentation in the base, several intermediate and last years reported in Annex 3.2.9 (Table A3.2.9.1).



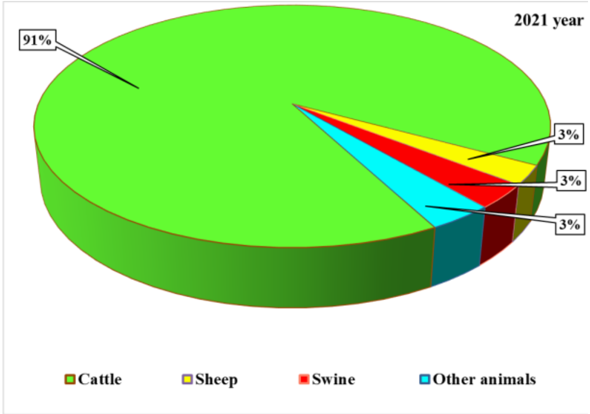


Fig. 5.3. Contribution of animal groups into the total methane emissions from enteric fermentation, %

Analysis of Table A3.2.9.1 leads to the conclusion that the highest emissions in this category produced by cattle enteric fermentation, providing for over 91 % of the total GHG emissions in this category. The next largest source of methane emission is enteric fermentation of sheep, swine and other animals, the total contribution to the overall emissions of which is much smaller (Fig. 5.3).

5.2.2 Methodological issues

5.2.2.1. The methodology for CH_4 emissions estimation from cattle enteric fermentation

Methane emissions from cattle enteric fermentation (Annex 3.2.9, Table A3.2.9.1) estimated according to Tier 2 from 2006 IPCC Guidelines [1]. Institute of Animal Science of the NAASU since 1985 explores different methodologies for calculation GHG from cattle enteric fermentation hold their adaptation with the conditions of Ukraine. We will be able to improve quality of emissions estimation from cattle enteric fermentation after testing the results of their research.

Equation 10.19 [1] used for GHG emissions calculation from cattle enteric fermentation (Table 5.4).

Cattle EF (Annex 3.2.8, Table A3.2.8.1) calculated in accordance with Equation 10.21 [1].

Gross energy intake. Calculation of GE (Annex 3.2.2, Table A3.2.2.1), according to Equation 10.16 [1], required definition of the following components:

– net energy required by the animal for maintenance (Equation 10.3 [1]);

– net energy for animal activity (Equation 10.4 [1]);

– net energy for lactation (Equation 10.8 [1]);

– net energy required for pregnancy (Equation 10.13 [1]);

– ratio of net energy available in a diet for maintenance to digestible energy consumed (Equation 10.14 [1]);

– net energy needed for growth (Equation 10.6 [1]);

– ratio of net energy available for growth in a diet to digestible energy consumed (Equation 10.15 [1]);

– digestible energy expressed as a percentage of GE (Table 5.4).

Activity data sources that used for cattle sex-age groups gross energy estimation reported in Table 5.4.

Table 5.4. Characteristics of AD sources for cattle GE estimation

AD name	Symbol	Source	Note
Weight coefficient for each cattle sex-age group	Cf	2006 IPCC Guidelines	Table 10.4

AD name	Symbol	Source	Note
Coefficient corresponding to animal's feeding situation for each cattle sex-age group	C_a	2006 IPCC Guidelines	Table 10.5
Coefficient for live body weight of an adult animal	C	2006 IPCC Guidelines	A coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls
Average live body weight of the animals in the population	Weight (for Equation 10.3) or BW (for Equation 10.6)	Country specific standards [3-5]	Annex 3.2.2, Tables A3.2.2.2 - A3.2.2.4
Mature live body weight of an adult animal in moderate body condition	MW	Country specific standards [3-5]	Annex 3.2.2, Tables A3.2.2.2 - A3.2.2.4
Average daily weight gain of the animals in the population	WG	Country specific standards [3-5]	Annex 3.2.2, Table A3.2.2.5
Amount of milk produced	Milk	SSSU ("Milk production", Table No.15) and analytical study [2]	Annex 3.2.2, Table A3.2.2.6
Fat content of milk	Fat	SSSU	Annex 3.2.2, Table A3.2.2.6
Pregnancy coefficient	$C_{pregnancy}$	2006 IPCC Guidelines	Table 10.7
Digestible energy	DE	SSSU; expert judgment from the NAASU (№13700/10-16 on 13 Dec 2016)	Annex 3.2.2, Table A3.2.2.7

Livestock. In line with the requirements of [1], data of the SSSU used as the information base to estimate the average annual cattle livestock (Table 5.3; Annex 3.2.1.3, Tables A3.2.1.3.1 and A3.2.1.3.2).

Methane conversion factor. Methane conversion factor (Y_m) for cattle (for dairy cows and other cattle as 6.5 %) used from Table 10.12 [1].

5.2.2.2. The methodology for CH_4 emissions estimation from sheep enteric fermentation

Tier 2 used for methane emissions from sheep enteric fermentation calculation [1]. According to them, to estimate methane emissions, it is necessary to determine:

– the amount of GE intake (Annex 3.2.2, Table A3.2.2.8);
– number of sheep (Table 5.3; Annex 3.2.1.3, Table A3.2.1.3.1);
– methane conversion factor (Table 10.13 [1]).

Estimation of methane emissions from sheep enteric fermentation (Annex 3.2.9, Table A3.2.9.1) carried out according to Equation 10.19 of 2006 IPCC Guidelines [1].

Sheep EF by sex-age groups calculated in accordance with Equation 10.21 [1] and reported in Table A3.2.8.2 (Annex 3.2.8).

Gross energy intake. Calculation of GE, according to Equation 10.16 [1], required definition of the following components:

– net energy required by the animal for maintenance (Equation 10.3 [1]);
– net energy for animal activity (Equation 10.5 [1]);
– net energy for lactation (Equation 10.9 [1]);
– net energy required for pregnancy (Equation 10.13 [1]);
– ratio of net energy available in a diet for maintenance to digestible energy consumed (Equation 10.14 [1]);
– net energy needed for growth (Equation 10.7 [1]);
– net energy required for production of wool during a year (Equation 10.12 [1]);

– ratio of net energy available for growth in a diet to digestible energy consumed (Equation 10.15 [1]);

– digestible energy expressed as a percentage of GE (Table 5.5).

Activity data sources that used for seep sex-age groups gross energy estimation reported in Table 5.5.

Table 5.5. Characteristics of AD sources for sheep GE estimation

AD name	Symbol	Source	Note
Weight coefficient for each sheep sex-age group	Cf	2006 IPCC Guidelines	Table 10.4
Coefficient corresponding to animal's feeding situation for each sheep sex-age group	C_a	2006 IPCC Guidelines	Table 10.5
Coefficient for live body weight of an adult animal	C	2006 IPCC Guidelines	A coefficient with a value of 0.8 for females, 1.0 for castrates and 1.2 for bulls
Average live body weight of the animals in the population	Weight	Country specific standards [6-7]	Annex 3.2.2, Tables A3.2.2.9 - A3.2.2.12
The weight gain	WG_{lamb}	2006 IPCC Guidelines	Equation 10.7
The live bodyweight at weaning	BW_i	Country specific standards [6-7]	See description below
The live bodyweight at 1-year old or at slaughter (live-weight) if slaughtered prior to 1 year of age	BW_f	Country specific standards [6-7]	See description below
Constants for sheep net energy for growth calculation	a, b	2006 IPCC Guidelines	Table 10.6
Amount of milk produced	Milk	SSSU ("Milk production", Table No.15) and analytical study [2]	Annex 3.2.2, Table A3.2.2.9
The net energy required to produce 1 kg of milk	EV_{milk}	Country specific standards [9]	4.75 MJ × kg $^{-1}$
Annual wool production per sheep	$Production_{wool}$	SSSU [10] and analytical study [2]	Annex 3.2.2, Table A3.2.2.9
The energy value of each kg of wool produced	EV_{wool}	2006 IPCC Guidelines	A default value of 24 MJ × kg $^{-1}$
Pregnancy coefficient	$C_{pregnancy}$	2006 IPCC Guidelines	Table 10.7
Digestible energy	DE	Expert judgment from the NAASU (№20009/10-17 on 04 Aug 2017)	67.5 %

For the purposes of the inventory, average values of live weight of ewes and rams were used [6-7], estimated based on the average live weight of sheep by breeds and breed types, their breed composition structure.

Weaning of lambs for the purpose of feeding and fattening is done at the age of 3 months (live weight – 24 kg). The live weight of lambs at weaning at the age of 4 months for the purpose of herd replacement on average is 30 kg, of young replacement stock at the age of 1 year (mostly female lambs) – 50 kg, of feeding livestock at slaughter – approximately 49 kg, and of wethers – 60 kg [6-7].

Information about the method of sheep feeding obtained based on an expert judgment of the National University of Life and Environmental Sciences of Ukraine.

Maintenance of sheep characterized by long (on average about 270 days) grazing in large pastures. Sheep grazing is accompanied by constant migrations (several kilometers a day), as a consequence they spend a considerable amount of energy to receive fodder. The rest of time sheep stay in sheep pens, around which they arrange a fold for the animals' feeding and walking (the pasture-stall system). A number of farms in the steppe zone of the country successfully apply the pasture-semistall system with partial grazing of sheep in winter dry and cold weather with temperatures down to -8°C on winter crops, natural pastures, swamps. Ewes a month before calving and for 3 weeks after, as well as youngsters, not grazed. Sheep pasture system not practiced in Ukraine due to the high rate of land plowing [8].

Milking capacity of ewes depends on the breed, individual characteristics, age (yields increased up to the age of five years and then go down), maintenance conditions, and feeding [8]. The lactation period of sheep in the conditions of Ukraine is on average 4 months. According to the SSSU, the milking herd of ewes founded in the several key regions: Vinnytska, Ivano-Frankivska, Odesska, Chernivetska Oblast, and the Autonomous Republic of Crimea.

To estimate the rate of sheep milk production, data from SSSU observations ("Milk production", Table No.15) and analytical study [2] were used, but with adjustments to account for the sheep milk used in the suckling period for feeding lambs. In particular, in the estimations it assumed that the amount of milk consumed by lambs prior to weaning from ewes on average is 60 kg (expert assessment based on materials of the Ukrainian literature review [7-8]). The energy value of sheep milk taken in accordance with [9] as equal to 4.75 MJ/kg.

There are no statistics in the country on the proportion of sheep that give birth to one, two, or three lambs in the total population of ewes, which are required to determine the net energy required for pregnancy (NE_p). Therefore, it assumed that all the ewes during the year are pregnant, and the coefficient corresponding to the average number of lambs born in a year defined based on Table A3.2.2.9 (Annex 3.2.2). The average value of the pregnancy coefficient ($C_{pregnancy}$ = 0,087290) was calculated using the default values from Table 10.7 [1].

The value of digestibility of fodders for sheep (for good pastures, well preserved forages and feeding regimes based on forage with the addition of grain) was taken as 67.5 % on base of expert judgment from the NAASU (№20009/10-17 on 04 Aug 2017).

Livestock. SSSU data used as the information base to estimate the average annual sheep livestock (Table 5.3; Annex 3.2.1.3, Table A3.2.1.3.1).

Methane conversion factor. Default methane conversion factors from Table 10.13 [1] used for GHG estimation. According to this table, the methane conversion factor is 0.065 rel. units for animals older than 1 year, and for youngsters it is 0.045 rel. units. Since the livestock of sheep fattening are both youngsters (83.5 %) and adult animals (16.5 %) [6], the weighted average calculated, which corresponds to the mark 0.0483 rel. units.

5.2.2.3. The methodology for CH_4 emissions estimation from other animals enteric fermentation

Estimation of GHG emissions from the vital activity of animal species like goats, horses, swine, mules and asses, rabbits, fur-bearing animals, camels and buffaloes (Annex 3.2.9, Table A3.2.9.1) was performed under Tier 1 method (Equation 10.19) with the default emission factors (Table 10.10) [1]. The emission factors used to calculate emissions reported in Table A3.2.8.3 (Annex 3.2.8).

The values of the horses, goats, swine, mules and asses, rabbits, fur-bearing animals, camels and buffaloes average annual population used in the GHG inventory reported in Table A3.2.1.3.1 (Annex 3.2.1.3).

Data on the live weight of rabbits were obtained from analysis of literature materials [8] and make up 3.8 kg (the average for all breeds bred in Ukraine). The value of the live weight of fur-bearing animals of 4.1 kg was calculated as average between the data on the weight of minks – 2.1 kg, polar foxes – 5.0 kg, foxes – 4.9 kg, and nutria – 6.5 kg [8]. As animals with a similar digestive system for rabbits were mules and asses, whose live weight is 130 kg, for fur-bearing animals – swine (the live weight – 50 kg).

5.2.3 Uncertainty and time-series consistency

Uncertainty estimated in accordance with the Tier 1 methodology from 2006 IPCC Guidelines [1].

The uncertainty of emission estimation in category 3.A Enteric Fermentation is determined by uncertainties of AD and EF. Ranges and sources of uncertainty of input data used in calculation of national EF from cattle and sheep enteric fermentation reported in Table 5.6.

Table 5.6. The uncertainty of input data used in calculation of national emission factors from cattle and sheep enteric fermentation, %

Indicator	Measurement unit	Uncertainty	Source
Cattle			
Statistical data on livestock	thsd. head	6	Expert judgment based on SSSU data
Cf coefficient	MJ × day^{-1} × kg^{-1}	20	2006 IPCC Guidelines [1]
C_a coefficient corresponding to animal's feeding situation	MJ × day^{-1} × kg^{-1}	20	2006 IPCC Guidelines [1]
C coefficient	dimensionless	20	2006 IPCC Guidelines [1]
Average live body weight data of the animals in the population (Weight/BW)	kg	1-35	Range of average body weight values depending on the breed and sex-age indicators, according to data of [3-5, 11]
MW mature live body weight of an adult animal in moderate body condition	kg	1-35	Range of average body weight values depending on the breed and sex-age indicators, according to data of [3-5, 11]
WG average daily weight gain of the animals in the population	kg	1-35	Range of average body weight values depending on the breed and sex-age indicators, according to data of [3-5, 11]
Statistical data on milk production	kg × day^{-1} × $head^{-1}$	6	Expert judgment based on SSSU data
Fat content of milk	%	6	Expert judgment based on SSSU data
$C_{pregnancy}$ pregnancy coefficient	dimensionless	20	2006 IPCC Guidelines [1]
DE digestible energy	%	± 20	2006 IPCC Guidelines [1]
Sheep			
Statistical data on livestock	thsd. head	6	Expert judgment based on SSSU data
Cf coefficient	MJ × day^{-1} × kg^{-1}	20	2006 IPCC Guidelines [1]
C_a coefficient corresponding to animal's feeding situation	MJ × day^{-1} × kg^{-1}	20	2006 IPCC Guidelines [1]
C coefficient	dimensionless	20	2006 IPCC Guidelines [1]
WG_{lamb} weight gain	kg	1-35	Range of average body weight values depending on the breed and sex-age indicators, according to data of [6-9]
BW_i live bodyweight at weaning	kg	4-7	Values depending according to [9]
BW_f live bodyweight at 1-year old or at slaughter	kg	10-18	Values depending according to [9]
a, b constants for sheep net energy for growth calculation	dimensionless	20	2006 IPCC Guidelines [1]
Statistical data on milk production	kg × day^{-1} × $head^{-1}$	6	Expert judgment based on SSSU data
EV_{milk} net energy required to produce 1 kg of milk	MJ × kg^{-1}	16	Value range according to data of [7]
Statistical data on wool production	kg × day^{-1} × $head^{-1}$	6	Expert judgment based on SSSU data
EV_{wool} energy value of each kg of wool produced	MJ × kg^{-1}	± 20	2006 IPCC Guidelines [1]
$C_{pregnancy}$ pregnancy coefficient	dimensionless	27	2006 IPCC Guidelines [1]
DE digestible energy	%	± 20	2006 IPCC Guidelines [1]
Methane conversion factor	rel. u	7-9	2006 IPCC Guidelines [1]

Estimation of GHG emissions for the reporting period carried out with the same method and the same degree of detail. Time series data collected and processed according to the agreed procedures.

The significant reduction in the population of cattle at agricultural enterprises as a result of the collapse of the Soviet Union and the subsequent restructuring of the agricultural sector led to the situation where the key impact on the trend of methane emissions from enteric fermentation is exerted by livestock dynamics in households (Fig. 5.4). Fig. 5.5 illustrates the dependence of the methane emission trend in category 3.A Enteric Fermentation on the cattle population, which is the major factor to regulate emissions.

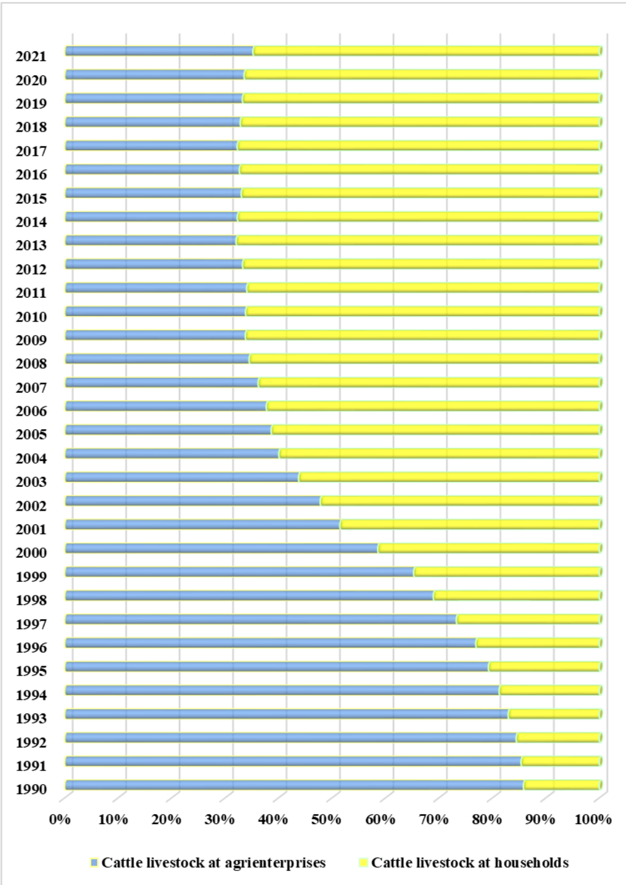


Fig. 5.4 Cattle livestock distribution between different kinds of farms

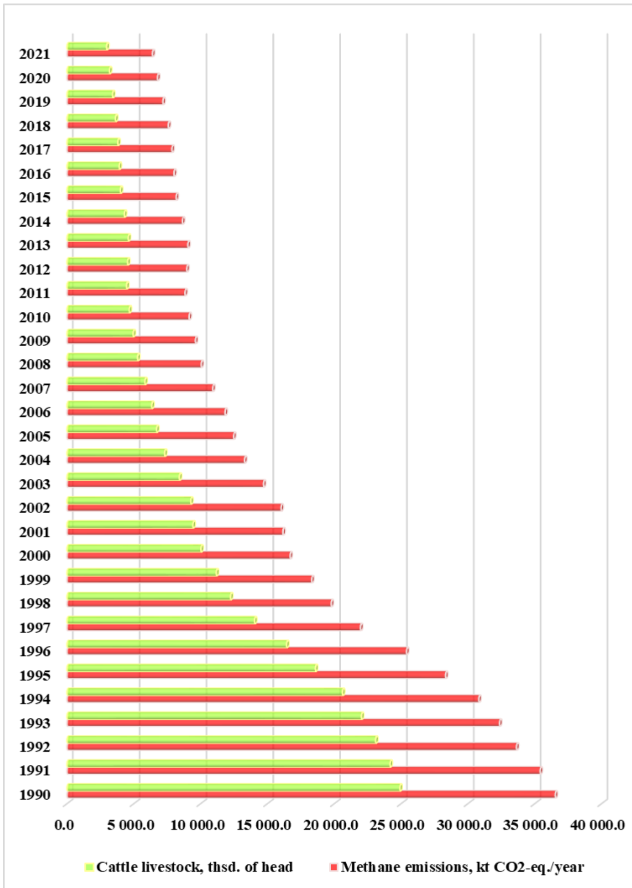


Fig. 5.5 Dependence of methane emission trends in category 3.A Enteric Fermentation on cattle population

5.2.4 Category-specific QA/QC procedures

Quality control and assurance carried out with general and detailed procedures, which include comparisons of activity data with similar FAO data, check of national EF by comparing them with the respective default coefficients [1] and coefficients of countries with similar conditions, etc.

Check of the GE values calculated for each sex-age group of cattle and sheep carried out by means of their conversion into food consumption units in the dry matter (kg × day^{-1} × $head^{-1}$) and comparison with live weight values of the corresponding cattle groups. According to results of the estimations conducted, daily dry matter intake for all groups of cattle and sheep is within the range specified in 2006 IPCC Guidelines [1].

Table 5.7. Comparison of methane emission factors from enteric fermentation with emission coefficients of Central and Eastern Europe countries*, kg × $head^{-1}$ × yr^{-1}

Indicator	Ukraine	Federal Republic of Germany	French Republic	Czech Republic	Slovak Republic	Hungary
Mature dairy cattle	114.03	140.79	126.61	159.45	122.17	128.96

Indicator	Ukraine	Federal Republic of Germany	French Republic	Czech Republic	Slovak Republic	Hungary
Mature non-dairy cattle**	45.72	48.44	52.94	58.95	61.24	55.70
Sheep	8.76	6.36	12.92	8.00	10.74	8.00

** Source: NIR of the Central and Eastern Europe countries, data for 2020, Ukraine – 2021 data.*
*** For reporting, Ukraine uses option B, therefore the emission factors shown for growing cattle, given its dominant share in the structure of non-dairy cattle herds.*

Methane emission factors from enteric fermentation of mature dairy cattle according to the CRF data compared with the default factor [1]. The difference in the estimations is due to differences in input data and the approaches used to estimate them.

A comparison of enteric fermentation EF for dairy and non-dairy cattle with the similar coefficients of Central and Eastern Europe countries has shown that they are in the same range (Table 5.7).

Also, a cross-analysis of factor time series and the totals of emissions from enteric fermentation of cattle was conducted according to CRF data (Fig. 5.6).

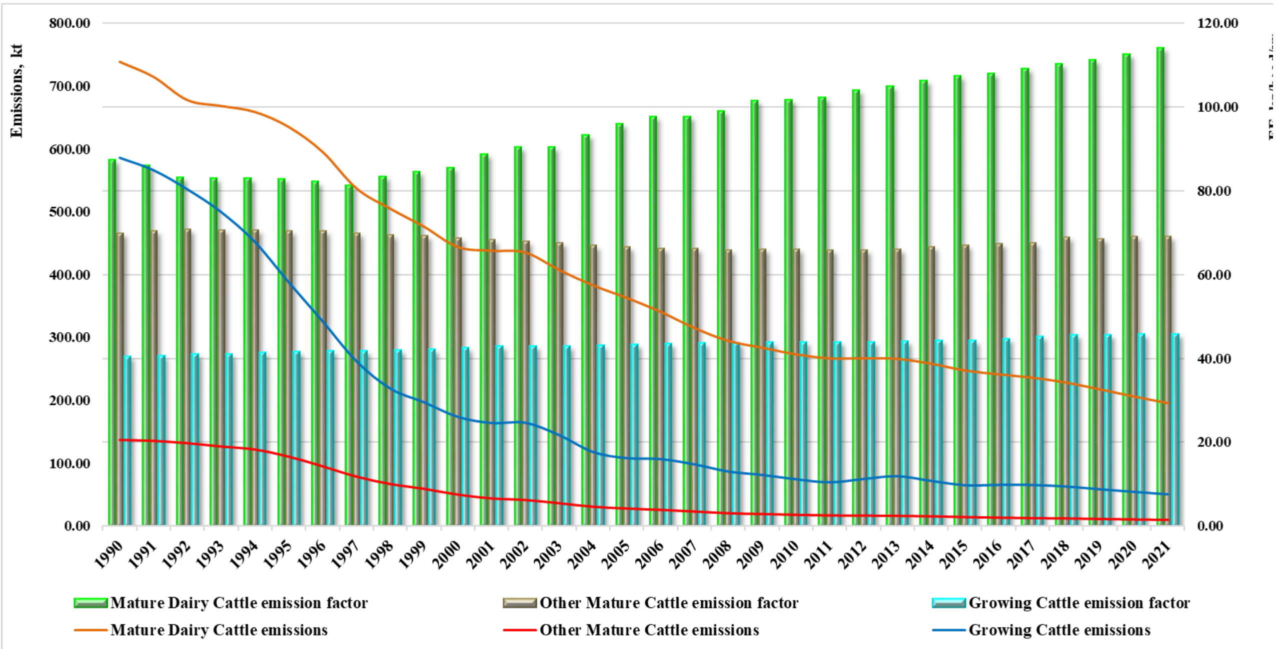


Fig. 5.6. Emission values and methane emission factors dynamics from cattle enteric fermentation

The results of comparison of national EF from sheep enteric fermentation according to CRF data with the default factors indicate the discrepancy within 0.6-12.0 % (the average for the reporting period – 6 %). Furthermore, the foregoing comparison of the sheep enteric fermentation EF’s, with the similar coefficients of Central and Eastern Europe countries has shown that they are in the same range (Table 5.7). The discrepancy of the factors in this case may be explain by the significant changes in the sheep livestock structure along the time series. In particular, the percentage of ewe and gimmers 1 year old and older population in the total herd structure in all categories of farms increased from 42 % in 1990 up to 67.2 % in 2021 with the proportional decrease in the share of growing sheep, to which the lowest EF apply.

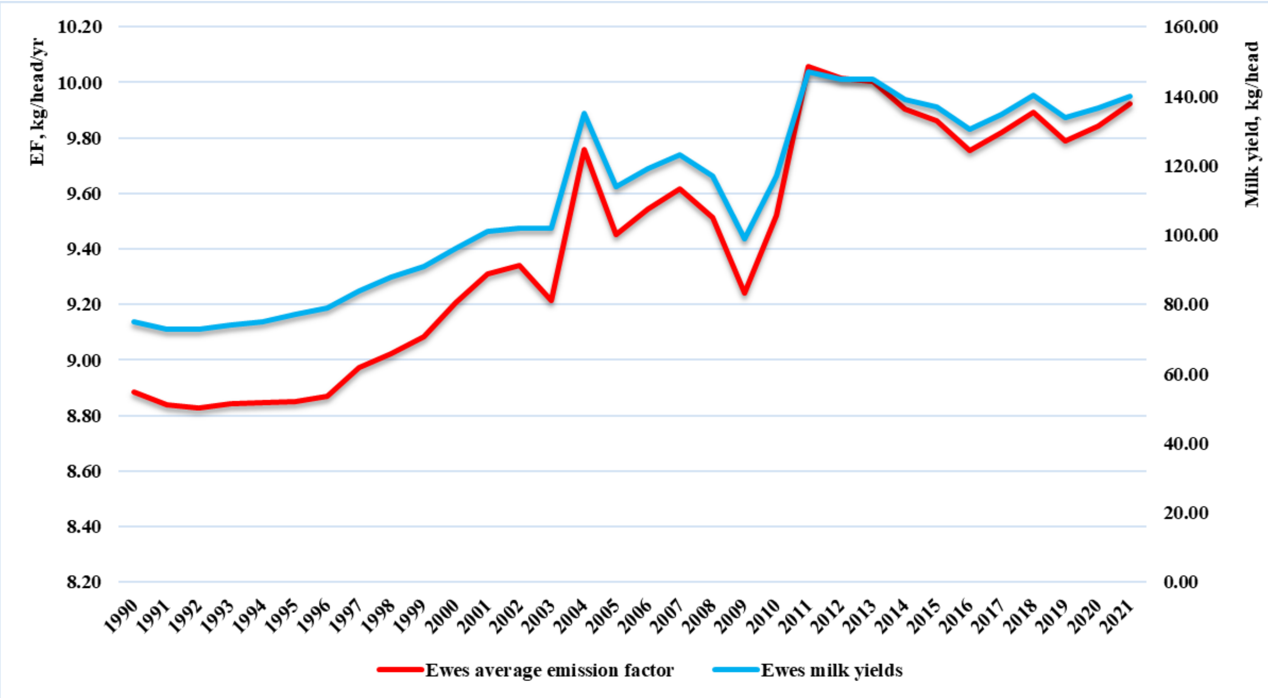


Fig. 5.7. The dependence of ewes EF on milk yield in 3.A Enteric Fermentation

The coefficients of methane emissions from enteric fermentation of ewes and gimmers is directly dependent on the amount of milk production, as shown on Fig. 5.7.

5.2.5 Category-specific recalculations

Methane emissions in 3.A Enteric Fermentation category were recalculated and reported in Annex 3.2.10 (Table A3.2.10.1).

There are several reasons for the methane emissions recalculation in the current category, but the main of them is a livestock data clarification by the FAO (camels, mules and asses – for 2017-2020).

5.2.6 Category-specific planned improvements

The Institute of Animal Science of the NAASU since 1985 explores different methodologies for calculation GHG from cattle enteric fermentation hold their adaptation with the conditions of Ukraine. We will be able to improve quality of emissions estimation from cattle enteric fermentation after testing the results of their research.

5.3 Manure Management (CRF category 3.B)

5.3.1. Category description

An important area of stock-raising is manure management, which leads to emissions of various GHG (Table 5.8), namely: methane (CH_4), nitrous oxide (N_2O), and non-methane volatile organic compounds (NMVOCs).

Table 5.8. Review of category 3.B Manure Management

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
3.B.1 Manure Management	CS, T 1, T 2	CS, D	CH_4	No	140.04	39.41	-71.86

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
3.B.2 Manure Management	CS, T 1, T 2	CS, D	N_2O	No	10.99	3.10	-71.82
3.B.2 Manure Management	T 1	D	NMVOC	No	198.77	60.15	-69.74

As a result of vital activity of a complex set of microorganisms in anaerobic conditions, methane fermentation takes place (the decomposition process of organic substances to end products, in particular to methane and carbon dioxide). The level of methane emissions from manure depends on the following key factors:

– manure storage conditions (in the liquid or solid form);
– type of climate (cold, temperate, or warm);
– composition of feed rations for animals;
– type of manure (cattle, swine, sheep, poultry manure, etc.);
– dry matter content in manure.

While agricultural enterprises in Ukraine mainly comply with the practice of manure storage in the liquid and in solid form, in the private sector manure is only stored in the solid form in clamps or remains in pastures. Methane emissions from solid storage are much lower than in the case of liquid storage, since a large part of it decomposed under aerobic conditions. However, such conditions become favorable for formation of another GHG – N_2O. This gas can be produced both when there is access of oxygen as a result of oxidative processes of NH_3 nitrification into NO_3, and in anaerobic conditions due to recovery denitrification processes.

There is a big fluctuation of GHG emissions in 3.B Manure Management category for a reporting period (Annex 3.2.9, Table A3.2.9.2).

Along the 2013-2021 period, a sharp reduction of CH_4 emissions from manure compared to the base 1990 observed. Primarily, this explained by the reduction in the main livestock species and groups due to the economic crisis in Ukraine that followed the collapse of the USSR. Besides, the downward trend of emissions in this category determined by the change in the manure management practice over the time series.

The main source of nitrous oxide emissions is the manure that is stored in the solid form. The significant reduction in N_2O emissions from all MMS during the reporting period was due to the reduced population of animals and decreased amount of nitrogen in the composition of manure stored in the solid form.

Fluctuation key for NMVOC emissions is animal's livestock.

5.3.2 Methodological issues

5.3.2.1 Methane emissions from Manure Management

Research paper "Development of the method to estimate and determine methane and nitrous oxide emissions as a result of manure management of animal and poultry: the final report on completion of the II (second) phase of the research work" [12] was conducted to evaluate national opportunities for estimation of CH_4 emissions from manure management. IPCC methodologies, some national methodological approaches, country specific and default EF's recommended by this paper.

Emissions of methane (Annex 3.2.9, Table A3.2.9.2) from manure estimated according to Equation 10.22 of 2006 IPCC Guidelines [1] and determines by the emission factor and livestock population (Table 5.3; Annex 3.2.1.3, Tables A3.2.1.3.1 and A3.2.1.3.2).

The information base on the population of animals for CH_4 emissions estimation (Annex 3.2.1.2) are statistical materials (Findings of cattle registry, Table No.7; Statistical reported data: "Number of agricultural animals as of January 01" [38]; Statistical bulletin: "The status of livestock in Ukraine" [13]; Statistical yearbook: "Animal Production of Ukraine" [10] and analytical study [2]. Cattle, swine, sheep, and poultry livestock at agrienterprises and households specialization by categories performed in accordance with Tables A3.2.1.1.1 and A3.2.1.1.2 of Annex 3.2.1.1.

Cattle, sheep, swine, and poultry methane EF's calculated in accordance with Equation 10.23 [1] and reported in Annex 3.2.8 (Table A3.2.8.4). Default EF from Tables 10.14 - 10.16 [1] used for estimation methane emissions from manure management of other animals and reported in Annex 3.2.8 (Table A3.2.8.3).

The next components used for EF estimation:

– maximum methane producing capacity (Annex 3.2.3, Table A3.2.3.1);

– volatile solid excretion rates (Equation 10.24 [1] for cattle and sheep and Equation 5.1 for swine and poultry; Annex 3.2.3, Table A3.2.3.3);

– methane conversion factors (Table 10.17 [1]; Table 5.10);

– manure management system usage (Annex 3.2.3 Table A3.2.3.2).

Maximum methane-producing capacity of the manure. Expert judgment was a source base for values of maximum methane-producing capacity for manure produced by cattle, sheep, swine, and poultry livestock (B_O). Its values reported in Table A3.2.3.1 of Annex 3.2.3.

Volatile solid excretion rate. The amount of volatile dry substances, which emitted from the cattle and sheep manure, calculated according to Equation 10.24 [1]. For swine and poultry, this factor obtained with Equation 5.1.

$$VS = MDM_{ex} \times (1 - ASH), \qquad (5.1)$$

where:

VS – volatile solid excretion per day on a dry-organic matter basis, kg VS day^{-1} (Annex 3.2.3, Table A3.2.3.3);

MDMex – amount of manure excreted by animals in dry matter, kg of dry mater day^{-1} (Annex 3.2.3, Table A3.2.3.1);

ASH – the ash content (inorganic component) of manure calculated as a fraction of the dry matter feed intake (Annex 3.2.3, Table A3.2.3.1).

Estimation of cattle, sheep, swine and poultry VS required definition of gross energy, digestible energy, urinary energy, ash content and amount of manure excreted by animals. Its sources reported in Table 5.9.

Table 5.9. Characteristics of AD sources for VS estimation

AD name	Symbol	Source	Note
Cattle			
Gross energy intake	GE	3.A Enteric Fermentation category (Chapter 5.2.2.1)	Table 5.4 Table A3.2.2.1 (Annex 3.2.2)
Digestible energy	DE	SSSU; expert judgment from the NAASU (№13700/10-16 on 13 Dec 2016)	Table 5.4 Table A3.2.2.7 (Annex 3.2.2)
Urinary energy expressed as fraction of GE	UE × GE	2006 IPCC Guidelines [1]	0.04 (Equation 10.24 description)
ASH content of manure	ASH	Expert judgment	Annex 3.2.3 Table A3.2.3.1
Sheep			
Gross energy intake	GE	3.A Enteric Fermentation category (Chapter 5.2.2.2)	Table 5.5 Table A3.2.2.8 (Annex 3.2.2)
Digestible energy	DE	Expert judgment from the NAASU (№20009/10-17 on 04 Aug 2017)	67.5 %
Urinary energy expressed as fraction of GE	UE × GE	2006 IPCC Guidelines [1]	0.02 (Equation 10.24 description)
ASH content of manure	ASH	Expert judgment *	Annex 3.2.3 Table A3.2.3.1
Swine			
ASH content of manure	ASH	Expert judgment	Annex 3.2.3 Table A3.2.3.1

AD name	Symbol	Source	Note
Amount of manure excreted by animals in dry matter **	MDMex	Expert judgment from the NAASU (№30432/10-17 on 28 Nov 2017) ***	Annex 3.2.3 Table A3.2.3.1
		Poultry	
ASH content of manure	ASH	Expert judgment	Annex 3.2.3 Table A3.2.3.1
Amount of manure excreted by animals in dry matter	MDMex	Expert judgment from the NAASU (№30432/10-17 on 28 Nov 2017) ***	Annex 3.2.3 Table A3.2.3.1

* – to determine the proportion of ASH in sheep manure, data on the content of organic substances in sheep manure (28 %) and its moisture content (64.6 %) resulting from the conducted studies [19-20] were used;
** – for swine at households, in accordance with the standards [14], the amount of manure excreted in dry matter is 30 % more than for agricultural enterprises, due to the peculiarities of feeding (diets of swine at agricultural enterprises dominated by concentrated fodders, whereas in households – multi-component fodders);
*** – the source of swine and poultry MDMex values is a judgment from the NAASU (№30432/10-17 on 28 Nov 2017), where they show an algorithm of its calculation according to "Departmental standards of technological design" [14-16].

Methane conversion factor. Default values of methane conversion factor (MCF) for each manure management system (MMS) used from the Table 10.17 [1]. MCF values for cattle, swine, sheep and poultry, that determined by current manure management systems, reported in Table 5.10.

Table 5.10. The kinds of manure management systems* that used in various types of livestock owners and their methane conversion factor values**

Animal species	MMS type	MCF value, %
Cattle at agrienterprises	Liquid system with natural crust cover	10
	Solid storage	2
	Pasture/Range/Paddock***	1
	Composting	0.5
Cattle at households	Solid storage	2
	Pasture/Range/Paddock***	1
Swine at agrienterprises	Uncovered anaerobic lagoon	66
	Liquid system with natural crust cover	10
	Solid storage	2
	Composting	0.5
	Aerobic treatment	0
Swine at households	Solid storage	2
Sheep (at all types of livestock owners)	Solid storage	2
	Pasture/Range/Paddock***	1
Poultry at agrienterprises	Poultry manure without litter	1.5
	Composting	0.5
Poultry at households	Poultry manure without litter	1.5
	Pasture/Range/Paddock***	1
Buffaloes (at all types of livestock owners)	Solid storage	
	Pasture/Range/Paddock***	
Horses (at all types of livestock owners)	Solid storage	
	Pasture/Range/Paddock***	
Goats (at all types of livestock owners)	Solid storage	
	Pasture/Range/Paddock***	
Mules and Asses (at all types of livestock owners)	Solid storage	
	Pit storage below animal confinements	
Camels (at all types of livestock owners)	Solid storage	
	Pit storage below animal confinements	

Animal species	MMS type	MCF value, %
Rabbits	Solid storage	
Fur farming	Solid storage	

** – the manure management systems characteristic according to 2006 IPCC Guidelines [1];*

*** – in this table reported only cattle, swine, sheep and poultry MCF values;*

**** – emissions from manure in Pasture/Range/Paddock are reported in 3.D Agricultural Soils.*

Manure management system. The main institution that collected all kinds of agricultural data is SSSU. But SSSU do not collect MMS data (fraction of livestock category manure handled using manure management system). To estimate these data the expert judgment from National University of Life and Environmental Sciences used as an alternative source for the time series MMS values estimation (Annex 3.2.3, Table A3.2.3.2).

There is a necessity to verify this expert judgment, because ERT has some important comments to it (ARR 2019, A 11-A 13 on p. 16; ARR 2017, A 10 on p. 19, A 23 on p. 47 and other). To solve this issue, MEPR has an offer to include a relevant research study to the List of high-priority improvements. However, due to the difficult political and economic situation in the country, conducting of this study is currently impossible and its timing is unknown yet. That is why for current MMS estimation this expert judgment used as main source with only one correction*.

** According to recommendation from «Potential Problems formulated in the course of the review of the 2015 and 2016 annual submissions of Ukraine and of the report to facilitate the calculation of the assigned amount for the second commitment period (10 September 2016)» MMS types for cattle manure managing were changed (MMS "Uncovered anaerobic lagoon", that recommended by expert judgment, was changed to "Liquid/Slurry" in accordance with official responses from several largest cattle enterprises).*

This judgment based on departmental standards of technological design of livestock MMS operating on the farms and complexes [9, 11, 14-16] and used some indirect SSSU data.

Due to lack of data, the cattle and swine manure distribution by systems estimated in accordance with the following sources:

– SSSU data of the agricultural animals livestock (Findings of cattle registry, Table No.7; Statistical reported data: "Number of agricultural animals as of January 01" [38]; Statistical bulletin: "The status of livestock in Ukraine" [13]);

– SSSU data of the statistical collection on the grouping of enterprises based on the available cattle and swine livestock (Statistical yearbook: "Animal Production of Ukraine" [10]);

– Statistical form "NO.1-Waste";

– Departmental standards of technological design of livestock MMS operating on the farms and complexes [11, 14, 16].

A departmental standards of technological design [16] determines a cattle and swine manure management systems planning at agrienterprises. The introduction of livestock enterprises is not allowed without the simultaneous introduction of MMS, which must conform to the manure characteristic and amount of its allocation. The amount and properties of manure depend on the type, age, diet and method of animals keeping and litter using.

According to standards [16], systems for manure managing have considered with the next marks: physical composition, removal method, storing method and duration, using method.

The manure with litter, manure without litter and slurry manure depends according to the method animals keeping.

Manure removal is carried by mechanical (conveyors, scraper installations, bulldozers) and hydraulic (uninterrupted gravity-flowing and periodic gravity-flowing systems) methods. Their using depends on period of manure storage, and animals keeping and feeding.

The storage period of all types of manure depends on the structure, humidity and technology of its storage and is 4–8 months for cattle manure and 8–12 months for swine manure.

Cattle and swine manure mostly used as natural fertilizer, and for biofuels production.

The choice of cattle and swine manure managing system is determined by the specific feasibility study and finally is a typical indicator of farm specialization and capacity.

Cattle and swine enterprises have several directions: dairy (only for cattle), beef, pregnancy/maternity, breeding etc. However, it is typically, that agricultural enterprises have a combined specialization, where these directions are combined. As a result, several manure managing systems can simultaneously use in a particular farm. But, only one specialization is a basic direction and defines the type of farm main manure managing system (other types of system can be ignored).

A farm capacity, except their specialization, is another criterion for MMS determination. Feasibility study determines [11, 14, 16] operating conditions of farms with different capacity (Table 5.11). SSSU provides a specific classification of cattle and swine enterprises (Annex 3.2.1.4, Table A3.2.1.4.1) in accordance with their capacity (they are grouped to simplify the report).

A judgment analysis states that manure storage practices at agricultural enterprises is significantly differ from manure storage practices at households (Table 5.10). Thus, the agricultural enterprises mainly comply with the practice of manure storage in the liquid and in solid forms, and in the private sector manure is only stored in the solid form in clamps or remains in pastures. In this regard, the data for these categories of farms estimated separately.

Table 5.11. Cattle and swine manure managing systems harmonization with the farm capacity [16]

Farm capacity	**Manure removal system [16]**	**Manure managing system [1]**	**Note**
Cattle at agrienterprises			
No more than 999 heads	Mechanical	Solid storage	Stable and stable-pasture types of cattle keeping with application of litter; outdoor keeping; calves keeping; maternity
More than 999 heads	Hydraulic	Liquid system	Cattle keeping without litter; silage, root crops, bard, pulp and green mass used for feeding
Swine at agrienterprises			
No more than 4999 heads	Mechanical	Solid storage	Swine keeping with litter; keeping technology provides, that feeding waste (mainly stems and tops) mixed with manure; maternity
5000-5999 heads	Hydraulic	Liquid system	Liquid and dry compound feeds used for feeding (without silage and green mass); keeping technology provides, that any feeding waste don't mix with manure
More than 5999 heads	Hydraulic	Uncovered anaerobic lagoon / Aerobic treatment	Liquid and dry compound feeds used for feeding (without silage and green mass); keeping technology provides, that any feeding waste don't mix with manure; accumulates for biofuel production

Solid and liquid systems, composting, and pasture/range/paddock are typical for cattle manure managing at agrienterprises. Manure stored in unconfined piles or stacks for a several months processed in solid systems. That manure fraction, which stored as excreted or with some minimal addition of water in either tanks or earthen ponds without mixing, is processed in liquid systems. According to expert judgment (№25334/10-16 on 11 Oct 2016), the period of manure storage in liquid systems is mainly up to 6 months.

Swine manure at agrienterprises managed in solid and liquid systems, by composting and aerobic treatment or uncovered anaerobic lagoons. There is typical manure specification for solid and liquid systems. Liquid manure with either forced or natural aeration or without aeration in lagoons properly stored in aerobic (aerobic treatment) and anaerobic (uncovered anaerobic lagoons) lagoons.

It is country specific that solid systems and pasture/range/paddock used for cattle and only solid systems – for swine manure managing at households.

At agricultural enterprises, poultry manure usually removed mechanically by a belt conveyor or a delta transporter in case the poultry kept in coop, and with the help of a bulldozer in case of floor keeping, and it is stored in piles or manure pits in the solid form.

For other types of animals (sheep, buffaloes, horses, goats, rabbits, fur-bearing animals, camels, mules and asses), there is also the common practice of manure management in the solid storage, pit storage below animal confinements, and pasture/range/paddock.

Manure in households is kept exclusively in clamps with litter (straw, sawdust, peat), or remains in paddocks. After several months of storage, the rotten manure brought to the field [17]. Therefore, the livestock and poultry manure rate by the MMS in households estimated according to expert estimation.

Duration of the grazing period depends on the regions where farm animals kept, while the average for Ukraine is 165 days [18]. According to [9, 11, 14-16], approximately 50 % of the annual amount of cattle and poultry manure remain on pasture, range or paddock. The same value for the amount of manure on pasture, range or paddock used in the calculations for goats, horses, and buffaloes (expert judgment from National University of Life and Environmental Sciences). As a fact that the majority of sheep, camels, mules and asses kept in Steppe, which have a high enough average annual temperature, the calculations reflect the fact that 74 % of the annual amount of sheep manure and 92 % of camels, mules and asses manure remain on pasture, range or paddock (the IPCC default data on distribution of manure of these animals by systems are representative for the Ukraine conditions).

5.3.2.2 Nitrous oxide and NMVOC emissions from Manure Management

5.3.2.2.1 Nitrous oxide emissions from Manure Management

Direct and indirect emissions estimated for a full N_2O evaluation from manure management systems (Annex 3.2.9, Table A3.2.9.2).

Research paper "Development of the method to estimate and determine methane and nitrous oxide emissions as a result of manure management of animal and poultry: the final report on completion of the II (second) phase of the research work" [12] was conducted to evaluate national opportunities for estimation of N_2O emissions from manure management. This paper recommends the IPCC methodologies, some national methodological approaches, country specific and default EF.

Direct N_2O emissions from manure management systems

Direct N_2O emissions from MMS estimated according to Equation 10.25 [1]. Thus, the estimate of nitrous oxide emissions in this category requires determination of the following indicators: livestock of cattle and poultry; amount of Nex in the composition of animal manure; shares of animal manure distribution by MMS; emission factors for each MMS.

Default [1] nitrous oxide EF from MMS reported in Table A3.2.8.5 (Annex 3.2.8).

The information base on the population of animals for N_2O emissions estimation (Annex 3.2.1.2 and Tables A3.2.1.3.1-A3.2.1.3.2 of Annex 3.2.1.3) are statistical materials (Findings of cattle registry, Table No.7; Statistical reported data: "Number of agricultural animals as of January 01" [38]; Statistical bulletin: "The status of livestock in Ukraine" [13]; Statistical yearbook: "Animal Production of Ukraine" [10] and analytical study [2]. Cattle, swine, sheep, and poultry livestock at agrienterprises and households specialization by categories performed in accordance with Tables A3.2.1.1.1 and A3.2.1.1.2 of Annex 3.2.1.1.

The same values of MMS for each animal group (Annex 3.2.3, Table A3.2.3.2) reported in Chapter 5.3.2.1 Methane emissions from Manure Management.

Based on the data available in Ukraine, the amount of Nex (Annex 3.2.3, Table A3.2.3.4) in manure composition of cattle sex-age groups was calculated in accordance with Equations 10.31-10.33. Cattle GE values (Annex 3.2.2, Table A3.2.2.1) for this estimation used from 3.A Enteric Fermentation (see Chapter 5.2.2.1). Crude protein fraction in diet of each cattle sex-age group calculated according to the judgment from the NAASU (№13700/10-16 on 13 Dec 2016) and reported in Table A3.2.3.7 (Annex 3.2.3). Database of milk production is SSSU source "Table No.15: Milk production", and for fat content in milk – expert judgment, which reported in Table A3.2.2.6 of Annex 3.2.2. Typical values of live weight for each sex-age cattle groups reported in Annex 3.2.2 (Tables A3.2.2.3 and A3.2.2.4). These values used for "Mature Dairy Cattle", "Other Mature Cattle" and "Growing Cattle" live weight calculation (Annex 3.2.2, Table A3.2.2.2).

Fodder consumption structure (Annex 3.2.3, Table A3.2.3.6) at all livestock owners and ratio of cattle sex-age groups at agrienterprises and households are the key drivers for Nex estimation. Agrienterprises and households have a fundamental difference in the cattle diet structure. The share of concentrated and succulent fodders at agrienterprises is over 60 % (more than 30 % of each type of fodders). Other fodders share mainly not more than 10 %. Another situation is typical for households, where the share of concentrated fodders – 9 %, succulent fodders – 12 %, coarse fodders – 30 % and other fodders – 49 %.

Sheep, swine and poultry Nex estimation based on the amount of manure excreted in dry matter and the proportion of nitrogen in it. These values calculated in accordance with the Equation 5.2 and reported in Annex 3.2.3 (Annex 3.2.3, Table A3.2.3.5):

$$N_{ex} = MDM_{ex} \times fn \times 365, \qquad (5.2)$$

where:

Nex – annual average N excretion per head, kg N animal^{-1} yr^{-1};

MDMex – amount of manure excreted by animals in dry matter, kg of dry mater day^{-1} (Annex 3.2.3, Table A3.2.3.1);

fn – fraction of nitrogen in manure dry matter from species/group of animals, dimensionless (Annex 3.2.3, Table A3.2.3.5).

The values of the amount of manure excreted in dry matter for swine and poultry were the same as those that used in Chapter 5.3.2.1 Methane emissions from Manure Management (also, see Table 5.9). Their source is a judgment from the NAASU (№30432/10-17 on 28 Nov 2017), where they show an algorithm of its calculation according to "Departmental standards of technological design" [14-16]. The source of sheep MDMex values (Annex 3.2.3, Table A3.2.3.1) is a NAASU judgment (№13700/10-16 on 13 Dec 2016).

The values of nitrogen fractions in dry matter (Annex 3.2.3, Table A3.2.3.5) of sheep, swine and poultry manure are standard [9, 14-16, 21].

For goats (Nex = 17.987), horses (Nex = 41.282), mules (Nex = 14.235), camels (Nex = 30.098) and buffaloes (Nex = 44.384) values of annual average N excretion per head estimated in accordance with Tables 10.19, 10A-6, 10A-9 and Equation 10.30 [1]. Nex for rabbits (Nex = 8.1) takes from Table 10.19 [1].

National statistics do not provide data to determine the population of fur-bearing species before 2004 (only total number of fur-bearing animals for 1990-2003, and fur-bearing livestock by species from 2004). In accordance with the ERT's recommendation (ARR 2015, Table 5, A.12), the weighted average Nex was calculated for fur-bearing animals from 2004. Furthermore, it is possible to calculate only average Nex for 1990-2003. There was a big difference between Nex values for 1990-2003 and 2004-present. That is why Nex rates for 1990-2003 have been revised with consideration with ERT recommendation (ARR 2016, Table 3, A.9) and taken as 4.672625 kg × head $^{-1}$ × yr $^{-1}$. Nex values for 1990-present period reported in Annex 3.2.3 (Annex 3.2.3, Table A3.2.3.4).

The amount N excretion determination per each MMS was performed using animal livestock values, the amount of Nex per head ×yr^{-1} and the proportion of manure processed in the corresponding system. Nex for cattle, sheep, swine and poultry was calculated on a more disaggregated level – separately for each gender and age groups of animals in the various farms categories. This approach takes into account the characteristics of different manure management sex and age groups of animals in the agricultural enterprises and households (Table 5.10), the corresponding average annual number of livestock and Nex (Annex 3.2.3, Tables A3.2.3.4-A3.2.3.5), and MMS typical share of processed manure (Annex 3.2.3, Table A3.2.3.2).

Indirect N_2O emissions from manure management systems

Indirect N_2O emissions includes the number of emissions that have occurred as a result of GHG leaching and volatilization from MMS. There is no national factor of N losses due to runoff and leaching during solid and liquid storage. That is why, the indirect N_2O emissions estimated from MMS volatilization only.

Manure management N_2O indirect emissions estimated according to Equation 10.27, where EF_4 – default value, and $N_{Volatilization\text{-}MMS}$ calculations based on Equation 10.26 [1].

Default value of fraction of managed manure nitrogen for livestock category that volatilizes as NH_3 and NO_X in the manure management system used for $N_{Volatilization\text{-}MMS}$ estimation. SSSU sources used for animal's livestock estimation. This data reported in Annex 3.2.1.2 and Tables A3.2.1.3.1-A3.2.1.3.2 of Annex 3.2.1.3. Annual average N excretion values used from previous section "Direct N_2O emissions from manure management systems" of current chapter. The same values of MMS for each animal group (Annex 3.2.3, Table A3.2.3.2) applied in Chapter 5.3.2.1 Methane emissions from Manure Management.

5.3.2.2.2 NMVOC emissions from Manure Management

To determine emissions of non-methane volatile organic compounds (NMVOC) from manure management systems, Tier 1 method was used [22]. In accordance with the methodological guidelines, estimation of NMVOC emissions from manure carried out according to Equation 5.3 [22]:

$$E_{pollutant\_animal} = \mathrm{AAP}_{animal} \times EF_{poluutant\_animal} , \qquad (5.3)$$

where:

$E_{pollutant\_animal}$ – pollutant emissions for each livestock category, tons yr^{-1} (Annex 3.2.9, Table A3.2.9.2);

AAP_{animal} – number of animals of a particular category that are present, on average, within the year;

$EF_{pollutant\_animal}$ – emission factor for each livestock species/category.

The information base on the population of animals for NMVOC emissions estimation (Annex 3.2.1.2 and Tables A3.2.1.3.1-A3.2.1.3.2 of Annex 3.2.1.3) are statistical materials (Findings of cattle registry, Table No.7; Statistical reported data: "Number of agricultural animals as of January 01" [38]; Statistical bulletin: "The status of livestock in Ukraine" [13]; Statistical yearbook: "Animal Production of Ukraine" [10] and analytical study [2]. Cattle, swine, sheep, and poultry livestock at agrienterprises and households specialization by categories performed in accordance with Tables A3.2.1.1.1 and A3.2.1.1.2 of Annex 3.2.1.1.

Table 5.12. Tier 1 EF for NMVOC by default

Livestock	**Tier 1 default EF for NMVOC, kg AAP^{-1}. a^{-1}**	
	with silage feeding	***without silage feeding***
Dairy cattle	17.937	8.047
Other cattle[1]	8.902	3.602
Fattening swine[2]	-	0.551
Sows	-	1.704
Sheep	0.279	0.169
Goats	0.624	0.542
Horses	7.781	4.275
Mules and asses	3.018	1.470
Laying hens (laying hens and parents)	-	0.165
Broiler chickens (broilers and parents)	-	0.108

Livestock	Tier 1 default EF for NMVOC, kg AAP^{-1}. a^{-1}	
	with silage feeding	*without silage feeding*
Other poultry (ducks, geese, turkeys)[3]	-	0.489
Fur-bearing animals	-	1.941
Rabbits	-	0.059
Reindeer[4]	-	0.045
Camels	-	0.271
Buffaloes	9.247	4.253

[1] *Includes young cattle, beef cattle and suckling cows*
[2] *Includes piglets from 8 kg to slaughtering*
[3] *Based on data for turkeys*
[4] *Assume 100% grazing*

Tier 1 standardized emission factors for NMVOC used by default [34] and reported in Table 5.12.

5.3.3 Uncertainty and time-series consistency

Uncertainty assessment calculated according to Tier 1 method [1].

Uncertainty of the inventory results in this category is determined by: the population of animals; the amount of volatile solid substances and nitrogen the composition of manure; the maximum methane producing potential; manure distribution by manure management systems; methane conversion factors; nitrous oxide emission factors; emission factors for NMVOCs.

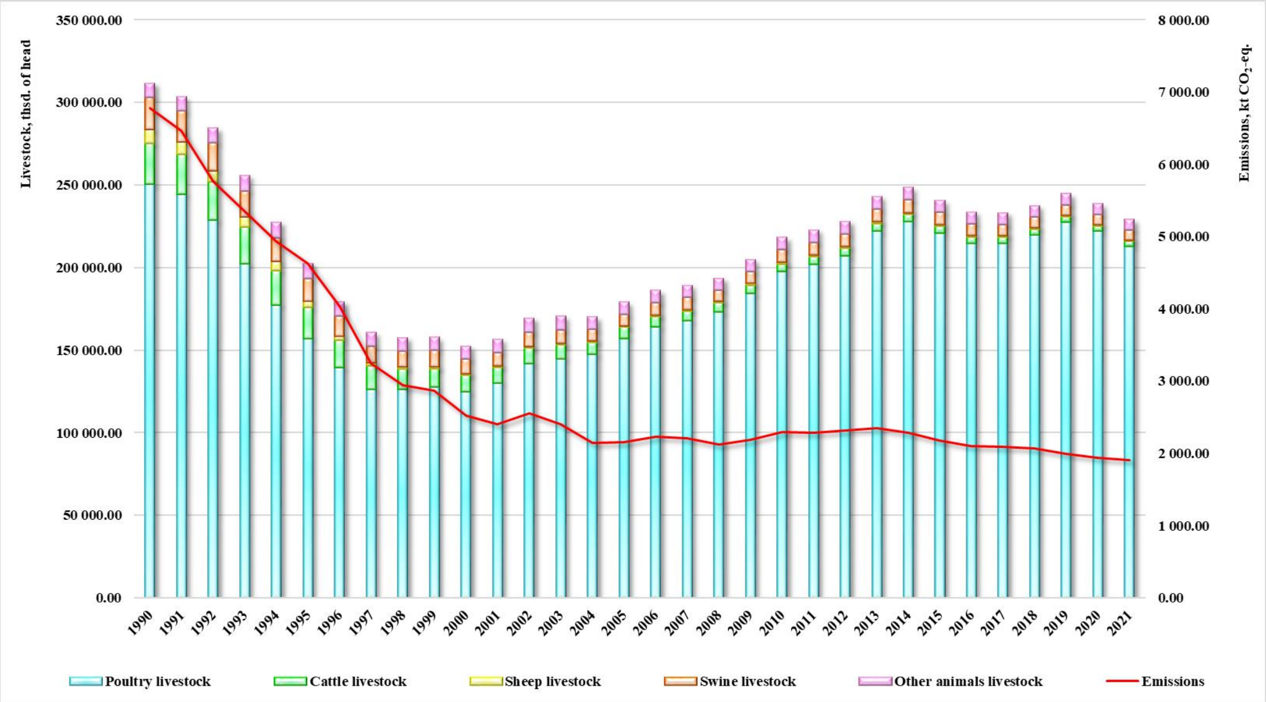


Fig. 5.8. Emission trends in category 3.B Manure Management, and those of cattle, swine, poultry and other animals' populations

The uncertainty of statistical data on the population of cattle and poultry evaluated at the level of 6 %. According to the expert judgment, the accuracy of standards of manure and litter excretion in the dry matter, of nitrogen fractions and ASH in it, as well as of data on manure distribution by species and sex-age groups of animals in the public and private sectors corresponds to the statistic uncertainty. Default uncertainty of methane emissions factors for goats, horses, camels, buffaloes, asses and mules, as well as rabbits and fur-bearing animals is 30 % [1].

The accuracy of national data on the number of emissions of volatile solid substances and nitrogen in the composition of manure/litter of cattle, pigs, sheep, and poultry calculated based on the standards corresponds to the mark of 7 %.

Table 5.13 shows uncertainties of the input data for estimating methane emission factors from manure and their sources.

Table 5.13. The uncertainty of data for calculation of national factors of CH_4 emission from Manure Management, %

Indicator	Measurement unit	Uncertainty	Source
Excretion of manure and litter	kg/head per day	5	State regulatory data
The proportion of ASH in manure and litter	rel. u	5	State regulatory data
The proportion of volatile solid substances and nitrogen in sheep manure	rel. u	5	Expert judgment
The maximum potential of methane emission from manure and litter	m^3/kg of VS	15	2006 IPCC Guidelines
Methane conversion factor for uncovered an-aerobic lagoons	rel. u	56	2006 IPCC Guidelines
Methane conversion factor for solid storage	rel. u	50	2006 IPCC Guidelines
Methane conversion factor for liquid system with natural crust cover	rel. u	42	2006 IPCC Guidelines
Methane conversion factor for pas-ture/range/paddock	rel. u	50	2006 IPCC Guidelines
Distribution of manure and litter by systems	rel. u	5	Expert judgment

The accuracy of default nitrous oxide emission factors based on [1] and constituted 50.0 %, and the estimated uncertainty of methane emission factors from manure was 19,13 %.

Estimation of methane and nitrous oxide emissions in category 3.B Manure Management in the reporting period was performed based on the same method, with the same level of detail. For activity data collection and processing for the entire time series, the SSSU applied harmonized methodologies. Fig. 5.8 shows diagrams of methane and nitrous oxide emissions from manure management, as well as that of the main types of livestock farm animals during the reporting period.

Against the background of the catastrophic decline in cattle population in the reporting period (approximately 5 times), a growth of poultry and swine population observed in recent years. Such divergent population trends are largely due to higher competitiveness of swine and poultry meat products in the market.

5.3.4 Category-specific QA/QC procedures

The general and detailed quality control and assurance procedures were applied to estimation of emissions in category 3.B Manure Management. In particular, according to the recommendations [1], a cross-check of the national values of volatile solids and nitrogen excreted during the reporting period was held by means of their comparison with the respective default values in 2006 IPCC Guidelines [1].

As part of the quality control procedures, national methane emission from manure factors were compared with the factors of Comparison of methane emission factors from enteric fermentation with emission coefficients of Central and Eastern Europe countries (Table 5.14). The main reasons of the EF's differences are the type of manure management systems and their range.

Table 5.14. Comparison of emission factors in 3.B Manure Management category*, kg/head per year

Emission factor	Ukraine	Federal Republic of Germany	French Republic	Republic of Austria	Czech Republic	Slovak Republic	Hungary
3.B Manure Management (methane emissions)							
Mature dairy cattle	4.20	23.24	11.06	17.12	13.28	8.33	30.50
Other mature cattle **	1.32	7.66	3.37	6.81	3.55	2.14	9.87

Emission factor	Ukraine	Federal Republic of Germany	French Republic	Republic of Austria	Czech Republic	Slovak Republic	Hungary
Sheep	0.24	0.28	0.35	0.31	0.19	0.39	0.29
Swine	3.04	4.78	4.14	1.26	2.00	2.58	3.53
Other livestock	0.05	0.04	0.03	0.04	0.11	0.03	0.03
3.B Manure Management (direct nitrous oxide emissions)							
Mature dairy cattle	0.30	0.62	0.40	0.80	0.58	0.79	1.18
Other mature cattle **	0.12	0.33	0.18	0.48	0.32	0.25	0.49
Sheep	0.02	0.03	0.02	0.07	0.04	0.09	0.07
Swine	0.09	0.06	0.004	0.09	0.05	0.07	0.05
Other livestock	0.002	0.002	0.001	0.003	0.004	0.002	0.004
3.B Manure Management (indirect nitrous oxide emissions)							
Atmospheric deposition	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Nitrogen leaching and run-off	NE	NO	0.01	NO	0.01	NA	0.01

** Source: NIR of the countries, data for 2020, Ukraine – 2021 data.*
*** For reporting, Ukraine uses option B, therefore the emission factors reported for growing cattle, given its dominant share in the structure of non-dairy cattle herds.*

The key factor determining trends of emissions from manure management of the main types of farm animals – cattle and swine – is the degree of utilization of liquid and anaerobic systems at agricultural enterprises. Moreover, a correlation analysis was conducted for national methane emission factors from manure of cattle and swine and the shares of these animals' manure by liquid and anaerobic systems for the reporting period (Fig. 5.9 and 5.10).

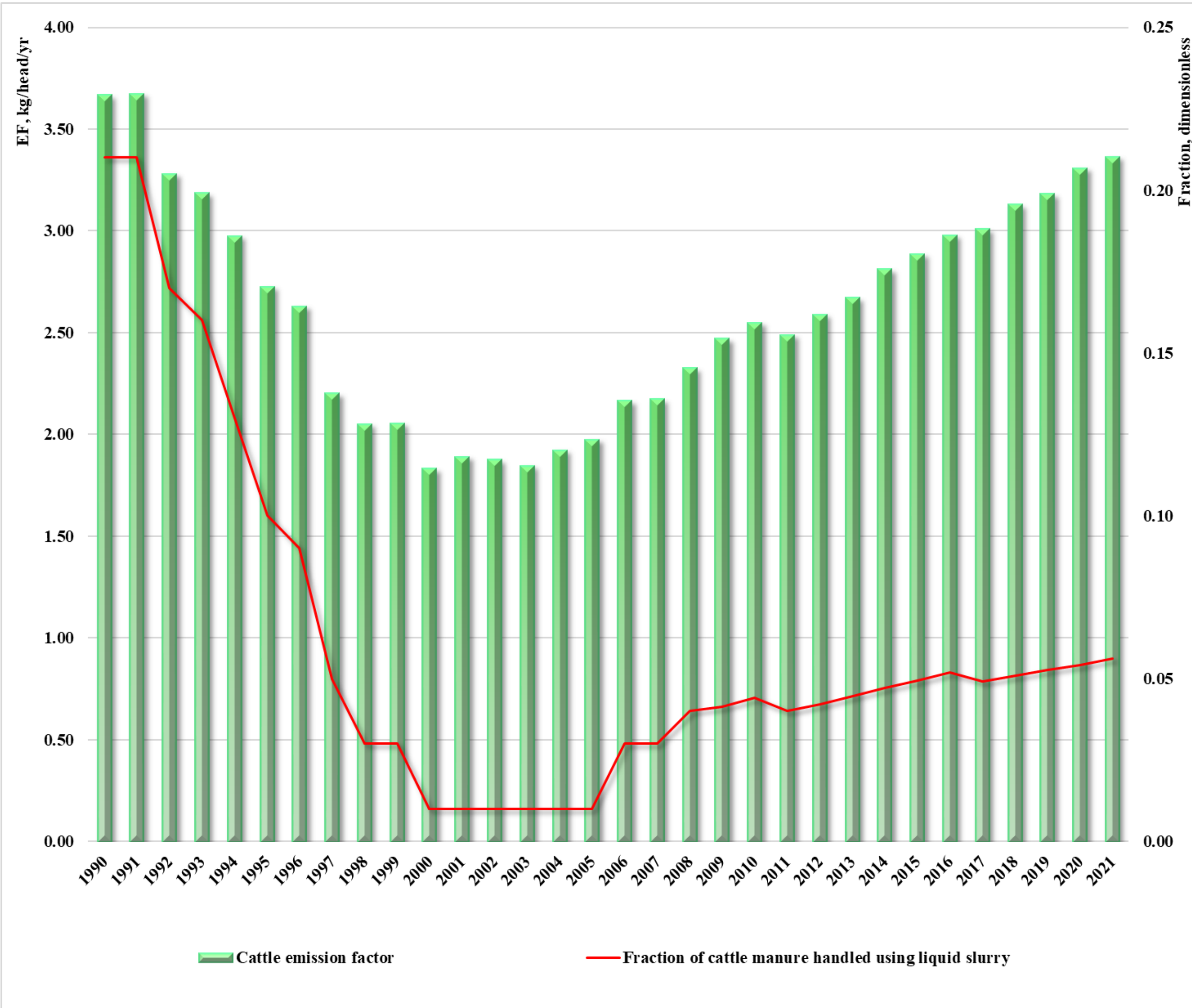


Fig. 5.9. Comparison of cattle emission factors and the shares of manure in MMS

Based on its results, it can be note that the trends of the emission factors and manure shares managed in anaerobic lagoons are closely related.

It should be noted that since 2005 (Fig. 5.9), there is a certain growth observed in the share of cattle manure in anaerobic systems in the manure management system distribution structure in the public sector (except for the last year). This pattern is due to the trend emerging in the recent years of expansion and construction of new large specialized dairy farms. Moreover, since 2006 there has been a clear trend of an increase in the share of swine manure processed in the liquid form, which is associated with the leading rate of swine population increase at large complexes with the capacity of 5,000 heads and more and manure storage systems in lagoons and manure pits in the slurry form, against the background of the total population of swine at agrienterprises.

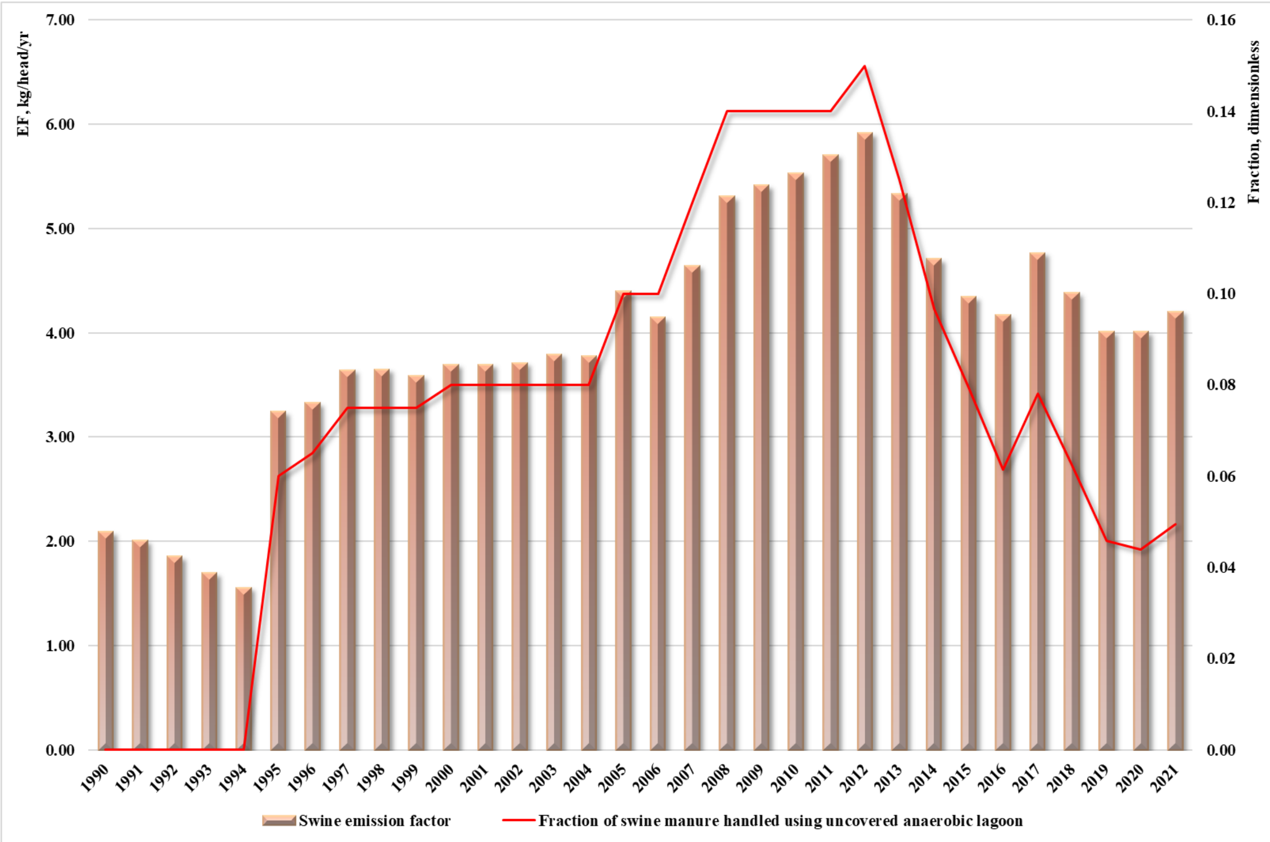


Fig. 5.10. Comparison of swine emission factors and the shares of manure in MMS

As part of quality assurance procedures, an independent expert review of the approaches and source data used to calculate emissions in category 3.B Manure Management performed.

5.3.5 Category-specific recalculations

Time series GHG emissions in 3.B Manure Management category recalculated and reported in Annex 3.2.10 (Table A3.2.10.2).

Recalculations in the 3.A Enteric Fermentation category is a reason for recalculations in the current category.

5.3.6 Category-specific planned improvements

Detailed MMS data for cattle, swine and poultry at agrienterprises manure distribution are not available. Special research is required to improve report in this category. To solve this issue, MEPR has an offer to include a relevant research study to the List of high-priority improvements. This study should resolve the following issues: MMS determination in accordance with 2006 IPCC

Guidelines; quantitative indicators of cattle, swine and poultry manure (tones), and its distribution (%).

Due to the difficult political and economic situation in the country, conducting of this study is currently impossible and its timing is unknown yet. However, all available data collected as a preliminary stage of this study.

5.4 Rice Cultivation (CRF category 3.C)

5.4.1. Category description

Rice cultivation is one of minor methane sources in Ukraine (Annex 3.2.9, Table A3.2.9.3). This fact explains the negligible GHG in category 3C Rice Cultivation (Table 5.15).

The annual amount of methane released from rice cultivation areas [1] depends on factors such as the area of rice fields, rice variety, the number of harvests, the duration of the culture cultivation, the water regime before and during the period of cultivation, the fertilization system, soil type, temperature. The key factor that affects the emissions volume is the area of rice fields (Annex 3.2.4, Table A3.2.4.1).

Table 5.15 Review of category 3C Rice Cultivation

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
Rice Cultivation	T1	D	CH_4	No	8.66	2.99	-65.42

In Ukraine, areas of rice fields are negligible. They were the lowest in 2021 and amounted to 10,100 hectares, and the largest – in 2011, 29,600 ha. In general, Ukraine has reducing rice cultivation areas. Changes in the rice harvesting areas directly cause the dynamics of methane emissions in the entire time series (Fig. 5.11) and determine the trend.

A sharp reduction in harvested rice acreage in 2014-2021 was due to absence of activity in the Autonomous Republic of Crimea.

5.4.2 Methodological issues

Methane emissions from rice cultivation were calculated according to Tier 1 of the 2006 IPCC Guidelines [1] based on SSSU data (Annex 3.2.4, Table A3.2.4.1) on rice harvested area and the number of organic fertilizers brought into the soil for this crop, as CH_4 emissions from rice cultivation are not the key category.

Based on information obtained from rice farms, rice fields in Ukraine characterized as constantly flooded ones. The commonly used types are those where the vegetation period is 120 days. Rice harvested once a year. Soil types used for rice cultivation – alkaline and brownstone alkaline.

Compost used as an organic fertilizer for rice (fermented fertilizers). Data on application of organic fertilizers for rice in 1991-1992 and 1994-1995 are not available from statistics, so the interpolation method was applied (Annex 3.2.4, Table A3.2.4.1).

A basic Equation 5.1 [1] used for calculations, and an adjusted daily emission factor (Annex 3.2.8, Table 3.2.8.6) was determined based on Equation 5.2 [1] of the 2006 IPCC Guidelines.

As a start point for calculations of the adjusted daily emission factor, the basic emission factor for fields without flooding for less than 180 days prior to rice cultivation and those continuously flooded during the rice cultivation period without organic fertilizers (EF_c) used. Its default value is 1.30 kg of CH_4 ha^{-1} per day (with the error range of 0.80 – 2.20, Table 5.11 of 2006 IPCC Guidelines) [1].

Several factors used for calculations:

– scaling factor to account for differences in water regimes during the cultivation period (SF_w) used as default data from Table 5.12 [1];

– scaling factor to account for differences in the water regime before the season, before the cultivation period (SF_p) – from Table 5.13 [1];

– scaling factor both for the type and amount of organic fertilizers applied (SF_o) that was calculated according to Equation 5.3. (Table 5.14) [1].

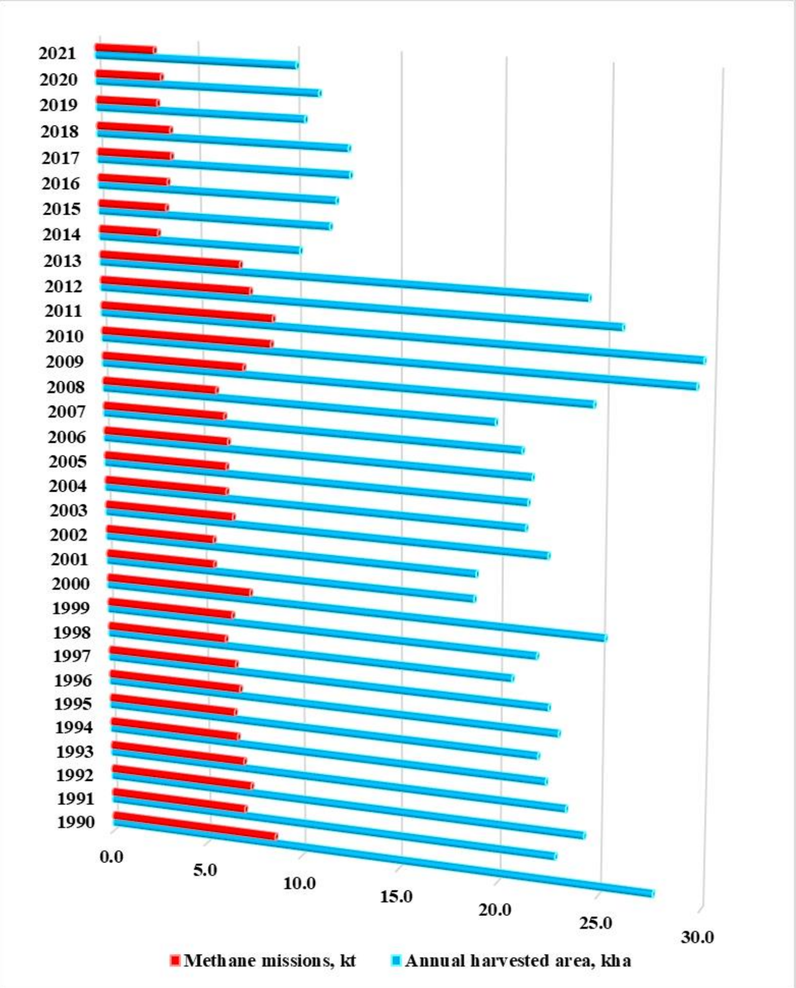


Fig. 5.11. Methane emissions and harvested area values fluctuation in 3C Rice Cultivation category

The input data, which used for methane emissions estimation from rice cultivation, reported in Table 5.16.

Table 5.16 Activity data for estimation of methane emissions from rice cultivation

Indicator	1990	1995	2000	2005	2010	2015	2020	2021
The baseline emission factor for continuously flooded fields without organic fertilizers (EF_c), kg of CH_4 ha^{-1} per day	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
The scaling factor to account for differences in water regime during the cultivation period (SF_w)	1	1	1	1	1	1	1	1
The scaling factor to account for the differences in water regime in the pre-season before the cultivation period (SF_p)	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
The scaling factor should vary for both type and amount of organic amendment applied (SF_o)	1.0544	1.0132	1.0021	1.0000	1.0009	1.0000	1.0000	1.0000
The adjusted daily emission factor for a particular harvested area (EF_i), kg of CH_4 ha^{-1} per day	2.60	2.50	2.48	2.47	2.47	2.47	2.47	2.47
The cultivation period of rice (t), days	120	120	120	120	120	120	120	120

5.4.3 Uncertainty and time-series consistency

Uncertainty estimation performed on base of Tier 1 method according to the methodology set out in Section 5.5.4, Volume 4 of the 2006 IPCC Guidelines [1].

The sources of uncertainty related to methane emissions from rice cultivation are various indicators (Table 5.17).

Table 5.17. Uncertainties in category 3.C Rice Cultivation

Indicator	Uncertainty, %
The scaling factor should vary for both type and amount of organic amendment applied (SF_o)	35.0
The baseline emission factor for continuously flooded fields without organic fertilizers (EF_c)	47.0
The scaling factor to account for differences in water regime during the cultivation period (SF_w)	23.0
The scaling factor to account for the differences in water regime in the pre-season before the cultivation period (SF_p)	14.0
The adjusted daily emission factor for a particular harvested area (EF_i)	15.14
The cultivation period of rice *(t)*	5
The annual rice harvested area *(A)*	6

To calculate the uncertainty of the conversion factor for compost, the basic emission factor for continuously flooded fields, the scaling factor to account for water regimes differences during the period of rice cultivation, and the scaling factor to account for differences in water regimes before the season, before the cultivation period, the corresponding error ranges used from Tables 5.11-5.14 of the 2006 IPCC Guidelines [1].

Over the entire reporting period, the same approach to collection of the basic information applied, and calculation of GHG emissions held on based of Tier 1 procedure from the 2006 IPCC Guidelines [1], which allowed forming consistent time series.

5.4.4 Category-specific QA/QC procedures

The general quality control and assurance procedures were applied to estimation of methane emissions as a result of rice cultivation.

Comparison of data on rice harvested areas with the same values used for estimation of emissions in the LULUCF sector showed that these data coincide.

5.4.5 Category-specific recalculations

Any recalculations of GHG emissions performed in the category 3C. Rice Cultivation.

5.4.6 Category-specific planned improvements

Any improvements planned in this category.

5.5 Agricultural Soils (CRF category 3.D)

5.5.1. Category description

Nitrous oxide emissions from soils occur naturally as a result of the microbial processes of ammonification, nitrification, and denitrification. However, application of nitrogenous fertilizer (nitrogen fertilizers, manure, crop residues) contributes into an increase in the amount of nitrogen involved in the processes of ammonification, nitrification, and denitrification, and ultimately – amount the N_2O emitted [23]. N_2O emissions in category 3.D Agricultural Soils reported in Table A3.2.9.4 of Annex 3.2.9 (also see Table 5.18).

Table 5.18. Review of category 3.D Agricultural Soils

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
3.D.1.1 Inorganic N Fertilizers	T1	D	N_2O	Level/Trend	28.89	31.40	8.66
3.D.1.2 Organic N Fertilizers	T1	D	N_2O		7.78	1.97	-74.63
3.D.1.3 Urine and Dung Deposited by Grazing Animals	T1	D	N_2O		10.59	3.17	-70.10
3.D.1.4 Crop Residues	CS	D	N_2O		46.26	37.59	-18.74
3.D.1.5 Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter	T2	D	N_2O		NO	19.91	NO
3.D.1.6 Cultivation of Organic Soils	T1	D	N_2O		5.99	5.93	-1.07
3.D.2.1 Atmospheric Deposition	T2	D	N_2O	Level/Trend	6.93	5.29	-23.64
3.D.2.2 Nitrogen Leaching and Run-off	T1	D	N_2O		19.99	20.83	4.21

During the observation period, there was redistribution of the share of emissions among sources in category 3.D Agricultural Soils (Fig. 5.12).

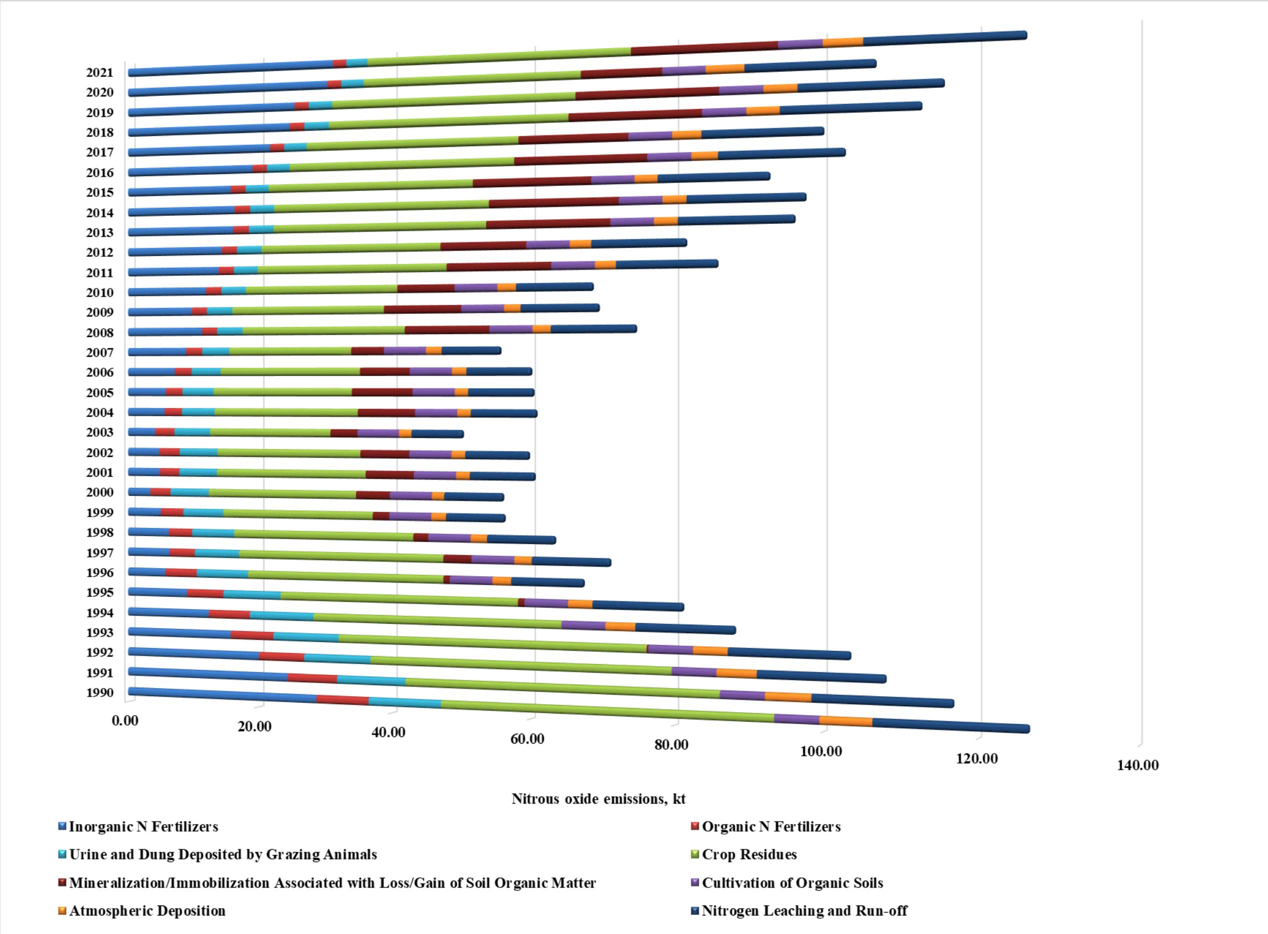


Fig. 5.12. Emission distribution in category 3.D Agricultural Soils

The key reasons for redistribution of shares of emissions in the category are the increase in emissions from crop residues and the reduction in other GHG sources, especially use of inorganic N fertilizers.

5.5.2 Methodological issues

5.5.2.1 Direct nitrous oxide emissions from agricultural soils

Sources of direct nitrous oxide emissions are [23]:
– application inorganic N Fertilizers (F_{SN});

– application organic N Fertilizers (F_{ON});
– urine and dung deposited by grazing animals (F_{PRP});
– crop residues, including nitrogen fixation (F_{CR});
– N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM});
– cultivation of organic soils (F_{OS}).

Research paper "Development of the method to estimate and determine nitrous oxide emissions from agricultural soils: the final report on completion of the II (second) phase of the research work" [23] conducted to evaluate national opportunities for estimation of N_2O emissions from agricultural soils. This paper recommended IPCC methodology [1], some national methodological approaches and default EF's (Annex 3.2.8, Table A3.2.8.7).

Direct emissions of N_2O estimated in accordance with Equation 11.1 from 2006 IPCC Guidelines [1].

Annual direct N_2O-N emissions from N inputs to managed soils

To calculate annual direct emissions of N_2O-N as a result of nitrogen application to managed soils, Equation 11.1 [1] used.

This equation will provide the values of F_{SN}, F_{ON}, F_{CR} and F_{SOM} for rice and the other crops. Activity data for determining the annual amount of inorganic N fertilizers, organic N fertilizers, N of crop residues and the N of mineralized soils for crops (and separately rice) are given in appropriate forms and SSSU bulletin and the results of analytical study [2].

According to Equation 11.1 [1], the indicators of the annual amount of nitrogen from inorganic fertilizers and manure, compost, sewage sludge and other organic nitrogen-containing additives brought under rice and the annual amount of nitrogen in crop residues of rice allocated separately and marked as FR.

Synthetic fertilizer. Nitrogen emissions from application of nitrogen fertilization calculated according to method that based on data from the statistical bulletin: "The application of synthetic and organic fertilizers for harvest of agricultural crops" [24] and analytical study [2]. FAO data (http://faostat.fao.org) and interpolation (Annex 3.2.5, Table A3.2.5.2) used for the years for which there are no statistical data (1991-1992 and 1994-1995). For managed soil application several types of synthetic N fertilizers used in Ukraine: ammonium hydroxide, calcium nitrate, ammonium nitrate, sodium nitrate, urea and others. However, SSSU provide only total annual amount values of these synthetic fertilizers (without their division into species) in 1990-2017 and from 2018 reports more detailed data where includes main kinds of simple and complex N fertilizers. The calculation of the annual amount of inorganic N fertilizers does not provide accounting losses of nitrogen in the ammonia and NO_X compounds form as the correction occurs during the EF determination [1].

Organic fertilizer. The annual amount of manure, compost, sewage sludge, and other organic nitrogen-containing additives introduced into soils was determined based on Equation 11.3 [1]. It should be noted that organic fertilizers (F_{ON}) consist only from annual amount of animal manure N (F_{AM}) and compost N (F_{COMP}; N_2O emissions from applied to soils compost N are reported in CRF Table 3.D as "[a. Direct N_2O emissions from managed soils] [2. Organic N fertilizers (3)] [c. Other organic fertilizers applied to soils]"). According to SSSU data sewage N (F_{SEW}) and N from other organic amendments that used as fertilizer (F_{OOA}) not applied on managed soils.

The annual amount of nitrogen in introduced into soils manure determined by Equation 11.4 [1]. Calculation of the amount of nitrogen in treated manure introduced into the soil, used for feeding, as fuel, or in construction based on Equation 10.34 [1]. National statistics do not keep records of the amount of treated manure used for feeding, construction, and as fuel, so $Frac_{FEED}$, $Frac_{FUEL}$, and $Frac_{CNST}$ not used for N_{MMS_Avb} estimation.

Estimation of the amount of N in the managed manure, which inputted into the soil, carried out without considering Composting MMS as compost taken into account when calculating the annual total amount of N in the compost F_{COMP}.

Moreover, the SSSU does not collect a data of the amount of N in sewage that introduced into soils (F_{SEW}). Also, they do not have a data on the amount of other organic improvers that used as fertilizers (F_{OOA}). Thus, these figures were not taken into account for estimation of the annual amount of manure, compost, sewage sludge, and other organic nitrogen-containing additives introduced into soils (F_{ON}).

Nitrogen, which inputted with the compost, taken into account only in F_{COMP}. Thus, the total annual amount of N in the compost F_{COMP} includes a compost that produced from plant residues and compost obtained through the managed manure.

The amount of N in compost that applied to soils calculated according to Equation 10.25 [1] using the values and the coefficient for the Composting MMS.

Crop residues. Estimation of nitrogen in crop residues carried out according to the national methodology, based on data on the biomass of plant residues plowed into the soil and the nitrogen content in them. Estimations of the amount of crop residues plowed into the soil carried out based on Levin's method quoted in the research paper [25] on the base of yield data for the key agricultural crop products. The amount of crop residues in crop sowed depends on biological properties of the cultivated plants, ecological (mainly soil and climate) conditions, the agricultural technologies and productivity levels, ways of sowing, seeding rates, and a number of other reasons. Therefore, when conducting the research, the results of which shown in Levin's paper, an attempt made to take into account the factors indicated above. For that sake, regression equations developed to determine the mass of plant residues based on the key product yields. The dependence of the amount of plant residues on crop growth is not always straightforward, so the biomass structure and the equations calculated for two yield levels – high and low. The advantage of Levin's method is that it provides for not only determination of the mass of side-products (hay, straw, tops, etc.) and surface residues (stubble) of crops, but also the mass of roots, making it possible to more comprehensively account for nitrogen in crop residues returned to soil. The values of the amount of plowed in side-products, stubble, and roots (in kilograms per hectare) for each crop calculated using the regression equations were then multiplied by the corresponding proportions of nitrogen and the total harvested area under the crop to assess the volume of nitrogen mineralized in soils in composition of plant residues in the national scope.

The number of side-products entering the soil was accounted for based on findings of the studies that showed that plowed in side-products are those of corn for grain, soybeans, potatoes, vegetables, sunflowers, as well as food and fodder melons. Straw, tops, and other side-products of other agricultural crops are harvested as forage or bedding for animals.

Estimation of nitrogen emissions as a result of crop residue return into soil was performed based on Equation 5.4 [25]:

$$F_{CR} = \sum_i \{[(a_i \times P_i + b_i) \times f_{ai} \times (1 - Frac_{Remove}) + (c_i \times P_i + d_i)] \times f_{ai} + (x_i \times P_i + y_i) \times f_{ri}\} \times S_i \times 10^2 , \qquad (5.4)$$

where:

i – agricultural crop type index;

P_i – yield of crop i, kg ha^{-1};

S_i – total harvested area under crop i with correction to the area that affected by the fires, ha;

a_i and b_i – regression coefficients for side-products of crop i;

c_i and d_i – regression coefficients for surface residues of crop i;

x_i and y_i – regression coefficients for roots of crop i;

f_{ai} – the proportion of nitrogen in the mass of side-products and surface residues of crop i, rel. u;

f_{ri} – the proportion of nitrogen in the mass of roots of crop i, rel. u;

EF_1 – nitrous oxide emission factor for mineralization of plant residues in soil, kg of N_2O-N kg^{-1} N;

$Frac_{Remove}$ – the number of side-products residues of a crop removed for feeding, bedding, and construction, kg of N kg^{-1} of N;

44/28 – the stoichiometric ratio between nitrogen content in N_2O-N and N_2O.

The values of yield and total harvested area of agricultural crops taken from the Statistical bulletin: "The area, gross harvesting and yields of crops, fruits, berries and grapes" [26] and analytical study [2]. The statistical bulletin contains data on all agricultural enterprises whose activities aimed at production of marketable agricultural products.

The estimations assumed that about 25 % of harvested areas under perennial grasses and herbage of cultivated pastures and hayfields renewed annually [27]. Similarly, to herbs, it assumed that each year 50 % of areas under biennial vegetables for seeds are renewed.

The sources of data on nitrogen fractions in underground and above-ground residues of most crops were national publications [17, 28-30]. For melons, coriander, broad beans, chick-peas, lathyrus and mung bean, spring rye, rice, barley, rape seeds, mustard and camelina, tobacco and wild tobacco, castor-oil beans, soybeans, sorghum, beans, and lupine data on nitrogen content were used in accordance with [1] or based on expert judgment.

For the crops where Levin's method offers no regression coefficients, the same data for biologically similar crops used. The information base for determining taxonomic similarity of crops was the reference book for identification of crop plants [31-32]. In particular, for soybean, vicia, beans, lupine, broad beans and chick-peas, lathyrus, mung bean data on pea (the legume family) used, for spring rye – data on winter rye were used, for rice – barley data, for sorghum – data on millet (the family of cereals), for crown flax – data on flax-fiber (the flax family), for tobacco and wild tobacco – potato data (the Solanaceae family), for rape seed, mustard, and camelina – data on annual grasses (the cruciferous family). In the absence of regression coefficients for the food and feed melons (the gourd family), the calculation based on vegetables. For vegetables, regression coefficients for coriander (Umbelliferae) used. Castor (the Euphorbiaceae family) correlated with sunflower (oilseed crops). In hayfields and managed pastures in the general herbage, there are perennial gramineous and leguminous grasses, so the corresponding regression coefficients used in the estimations.

Fires events stratified by timing of burning: before or after crop harvesting. If fires occurred before the crops have been harvest that is accounted by SSSU in the Statistical bulletin [26], where areas and yield of harvested crops reported. In the case of fires after crop harvest, regional departments of the SESU provided data of areas, which used for harvested area adjustment.

Regression coefficients depending on the crop yields, as well as the proportion of nitrogen in side-products, stubble and roots reported in Table A3.2.5.3 (Annex 3.2.5).

In the inventory, it assumed that the entire nitrogen accumulated by nitrogen-fixing rhizobia in roots of legumes accounted for when estimating emissions from mineralization of plant residues in soil.

Mineralized N. Country specific C:N ratio of the soil organic matter and ΔC used for F_{SOM} estimation according to Equation 11.8 [1]. More detail information about F_{SOM} estimation reported in Chapter 6.3 and Annex 3.3.2.

For N_2O-$N_{N\ Input}$ direct emissions, calculation default factors used from 2006 IPCC Guidelines [1].

Annual direct N_2O-N emissions from managed organic soils

The 2013 Wetlands Supplement contains updated EFs for direct N_2O emissions from drained organic soils in all land use. However, country specific AD not harmonized with 2013 Wetlands Supplement EFs. That is why estimation of GHG emissions from managed organic soils can based only on 2006 IPCC Guidelines.

The annual direct emissions of N_2O-N from cultivated organic soils calculations based on histosols area data and default EF (Table 11.1 of 2006 IPCC Guidelines) according to Equation 11.1 [1].

Data on areas of peat soils covering all of their types obtained from the State Agency of Water Resources of Ukraine. They are the most reliable ones, because they are based on information obtained directly the regional offices (Annex 3.2.5, Table A3.2.5.4).

Annual direct N_2O-N emissions from urine and dung inputs to grazed soils

Emissions of N_2O-N from animal manure on pastures ($N_2O–N_{PRP}$) estimated in accordance with Equation 11.1 [1]. In general, the methodology for estimating emissions in this category is similar to calculation of emissions from the other systems within category 3.B Manure Management. However, since manure from animals on pasture remains unharvested, emissions from this source should be estimated under category 3.D Agricultural Soils.

The annual amount of nitrogen from urine and litter deposited on pasture, range, and paddock by grazing animals was calculated according to Equation 11.5 [1], which is based on use of national data on the amount of N_{ex} in the MMS composition of manure (see Chapter 5.3.2).

The amount of nitrogen excreted in manure composition of species/category of cattle, sheep, swine, and poultry (N_{ex}) was calculated based on the amount of manure excreted in dry matter and the proportion of nitrogen in it using the Equations (10.31-10.3 from [1] and 5.2), as presented above (see Chapter 5.3.2.2.1) and reported in Tables A3.2.3.4-A3.2.3.5 of Annex 3.2.3.

The applied values of the proportion of total annual nitrogen emissions for each cattle species/category, which remains on pasture or paddock ($MMS_{(T, PRP)}$) were the same as in 3.B.1 Manure Management (methane emissions) category (see Annex 3.2.3, Table A3.2.3.2).

To estimate the emissions of N_2O-N from animal manure on pastures ($N_2O–N_{PRP}$), a default EF for N_2O emissions from nitrogen in urine and manure left by animals on pasture, range, and paddock was used [1].

5.5.2.2 Indirect nitrous oxide emissions from agricultural soils

Research paper "Development of the method to estimate and determine nitrous oxide emissions from agricultural soils: the final report on completion of the II (second) phase of the research work" [23] conducted to evaluate national opportunities for estimation of N_2O emissions from agricultural soils. This paper recommended IPCC methodology [1], country specific and default EF's (Annex 3.2.8, Table A3.2.8.7).

In addition to direct N_2O emissions from managed soils that happen directly from soil receiving nitrogen, N_2O emissions also occur through two indirect pathways – as nitrogen deposition from the atmosphere in the form of NH_3 and NO_X, and by leaching/runoff of introduced or deposited nitrogen.

The following sources of nitrogen for indirect N_2O emissions from managed soils that occur as a result of agricultural nitrogen introduction considered next positions:

– N of synthetic fertilizers (F_{SN});

– N of organic matter that applied as fertilizer (F_{ON});

– N of urine and dung deposited on pasture, range and paddock by grazing animals (F_{PRP});

– N in crop residues (above- and below-ground), including N-fixing crops and forage/pasture renewal returned to soils (F_{CR});

– N mineralization associated with loss of soil organic matter resulting from change of land use or management on mineral soils (F_{SOM}).

The type of N sources and their characteristic reported above in Chapter 5.5.2.1 Direct nitrous oxide emissions from agricultural soils.

Volatilization

Assessment of indirect N_2O emissions as a result of deposition from the atmosphere of nitrogen volatilized from managed soils was conducted according to Equation 11.1 [1].

Values of the annual amount of N from synthetic (F_{SN}) and organic (F_{ON}) fertilizers, and N from urine and dung left on pasture, range, and paddock by animals (F_{PRP}) calculated according to the corresponding equations, as described in Chapter 5.5.2.1 Direct nitrous oxide emissions from agricultural soils.

To estimate indirect N_2O emissions as a result of deposition from the atmosphere of nitrogen volatilized from managed soils, country specific share of nitrogen in synthetic fertilizers, which is volatilized as NH_3 and NO_X, used [33]. A spring application of synthetic N fertilizers is a widespread practice of its using, because inputting N, which inputted in autumn, leached in nitrate form. Gaseous losses of N make up 5-24 % [33] when fertilizers apply under the crop. A country specific middle value (14.5 %) of this diapason used for GHG emissions calculation (Annex 3.2.8, Table A3.2.8.7).

The share of nitrogen in organic nitrogen fertilizers introduced and nitrogen from urine and dung left by grazing animals, which volatilized as NH_3 and NO_X and the EF for N_2O emissions estimation from N volatilization taken as default values from 2006 IPCC Guidelines [1].

Leaching/Runoff

N_2O emissions from leaching and runoff of introduced or deposited nitrogen estimated using Equation 11.10 [1].

As described in Chapter 5.5.2.1 Direct emissions of nitrous oxide from agricultural soils, according to the respective equations the next values are calculate:

– F_{SN} (N from synthetic fertilizers);

– F_{ON} (organic fertilizers);

– F_{PRP} (N from urine and dung deposited by grazing animals on pasture, range and paddock);

– F_{CR} (N returned to soils with crop residues, including from N-fixing crops);

– F_{SOM} (annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management).

To estimate indirect N_2O emissions from leaching and runoff of introduced or deposited nitrogen, default values (Annex 3.2.8, Table A3.2.8.7) of the share of the total nitrogen added to managed soils or mineralized in cultivated soils that is lost through leaching and runoff, and EF for N_2O emissions from nitrogen leaching and runoff were applied [1].

5.5.3 Uncertainty and time-series consistency

Uncertainty assessment calculated in accordance with Tier 1 method [1].

The accuracy of emission data by source sub-categories within category 3.D Agricultural Soils depends on the AD and EF uncertainty. The uncertainty of statistical data on the amount of introduced mineral nitrogen fertilizers, crop yields, and harvested crop areas can used at the level of 6 % [2].

Table 5.19 shows uncertainties of the values nitrogen loss shares and their sources.

Table 5.19. The uncertainty of data of the fractions of nitrogen losses in category 3.D Agricultural Soils

Indicator	Uncertainty, %	Source
The fraction of nitrogen lost as NH_3 and NO_X at application of synthetic N fertilizers into soil	66	Value range according to data of [33] and expert judgment
The fraction of nitrogen lost as NH_3 and NO_X at manure storage in anaerobic lagoons	75	Value range according to data of [33] and expert judgment
The fraction of nitrogen lost as NH_3 and NO_X at liquid systems	38	Value range according to data of [33] and expert judgment
The fraction of nitrogen lost as NH_3 and NO_X in solid storage	33	Value range according to data of [33] and expert judgment
The fraction of nitrogen lost as NH_3 and NO_X at manure storage in other systems	33	Expert judgment
The fraction of nitrogen lost as NH_3 and NO_X at manure introduction into soil	50	2006 IPCC Guidelines [1]
The fraction of nitrogen lost as NH_3 and NO_X from manure on pasture	50	2006 IPCC Guidelines [1]

The fraction of nitrogen lost through leaching/runoff from introduced mineral nitrogen fertilizers in the Polissia	10	Expert judgment
The fraction of nitrogen lost through leaching/runoff from introduced mineral nitrogen fertilizers in the Wooded Steppe	35	Value range according to data of [33]
The fraction of nitrogen lost through leaching/runoff from introduced mineral nitrogen fertilizers in the Steppe	60	Value range according to data of [33]
The fraction of nitrogen lost through leaching/runoff from organic fertilizers introduced	43	Value range according to data of [33]

Uncertainties of activity data and default emission factors in category 3.D Agricultural Soils reported in Table 5.20.

Table 5.20. Activity data and emission factors uncertainties of reporting year in category 3.D Agricultural Soils, %

Name of the emission source	Activity data	Emission factors
Direct N_2O emissions	3.43	84.14
Indirect N_2O emissions	6.39	55.90

The same method with the same degree of detail used for the entire time series direct emissions estimation in 3.D Agricultural Soils category. The coordinated procedures for activity data collection and processing that used at the SSSU during the reporting period ensure a good succession of time-series.

5.5.4 Category-specific QA/QC procedures

General and detailed quality control and assurance procedures applied for estimation of direct and indirect N_2O emissions from agricultural soils. In particular, in accordance with the recommendations of [1], a comparison of data of the SSSU on the amount of N fertilizers introduced in the country with the same data from FAO was held. The comparison showed that during the years for which there is a statistical database, SSSU and FAO data on the amount of N fertilizers introduced virtually coincide for 1996-1999 (the difference is within 0.2 %) and closely coincide for 1994-1995 and 2005-2008. At the same time, for 1993, 2000-2004 and 2009-2021 these AD differ by 5-42 %, which may be due to use of the SSSU's preliminary data.

Such SSSU data as the amount of nitrogen introduced into soil as a component of fertilizer, crop yields and harvested areas are in line with the same data used in estimations for the LULUCF sector.

Moreover, the calculations performed analyzed the correlation between direct and indirect emissions, as well as between emissions from atmospheric deposition of nitrogen and leaching/runoff. The analysis showed that these data are well-agreed (the correlation coefficient in the both cases is close to one).

Assurance of the quality of direct emissions from agricultural soil estimations ensured by independent peer review of the national methodologies to estimate emissions at mineralization of plant residues by specialized experts.

5.5.5 Category-specific recalculations

Time series direct and indirect N_2O emissions in 3.D Agricultural Soils category recalculated as reported in Table A3.2.10.3 (Annex 3.2.10).

Recalculations in the 3.B Manure Management category is a reason for recalculations in the current category.

5.5.6 Category-specific planned improvements

Information about number of applied sewage sludge and other organic amendments are not available on database of SSSU and regional state agricultural departments. The issue of sewage sludge and other organic amendments using as an alternative type of organic fertilizer studies in the scientific articles. However, information about these studies' recommendations implementation is not available. It is planned to collect more data and improve this issue.

5.6 Prescribed Burning of Savannas (CRF category 3.E)

Estimation of GHG emissions in category 3.E Prescribed Burning of Savannas is not performed due to the fact that "Savannas" as an ecosystem does not exist in the territory of Ukraine.

5.7 Field Burning of Agricultural Residues (CRF category 3.F)

As above-mentioned in the text (Chapter 5.1), burning of agricultural residues in Ukraine is prohibited under the Code of Administrative Offenses (Art. 77-1) and the Law of Ukraine On Air Protection (Art. 16, 22).

In croplands, there are periodical fires that lead to burning of biomass from residues of various agricultural crops and, consequently, GHG emissions. The cause character of fires shows that we have classified them as wildfires. That is why emissions from burning of agricultural residues biomass on agricultural soils accounted in Cropland category of the LULUCF sector.

5.8 Liming (CRF category 3.G)

5.8.1. Category description

The contribution of category 3.G Liming in total GHG emissions is insignificant, which allows for estimation of CO_2 emissions with Tier 1 methodology (Table 5.21; Annex 3.2.9, Table A3.2.9.5).

Table 5.21. Review of category 3.G Liming

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
Liming	T1	D	CO_2	No	2592.08	176.23	-93.20

Emissions of carbon dioxide (CO_2) from the liming of agricultural soils (Fig. 5.13) decreased significantly over the time series.

The dynamics of emission reduction clearly demonstrate a sharp reduction from 1990 to 1991 and stabilization till 1995. From 1995 till 1997 there was the next stage of CO_2 emission reduction. The reduction of carbon dioxide emissions continued till 2003, but with smoother dynamics. Since 2004, there was a trend towards a gradual increase in the CO_2 emissions. In comparison with the previous year, in 2021 carbon dioxide emissions increased by 34.17 %; this was caused by the dynamics of annual inputted liming materials (Annex 3.2.6, Table A3.2.6.1).

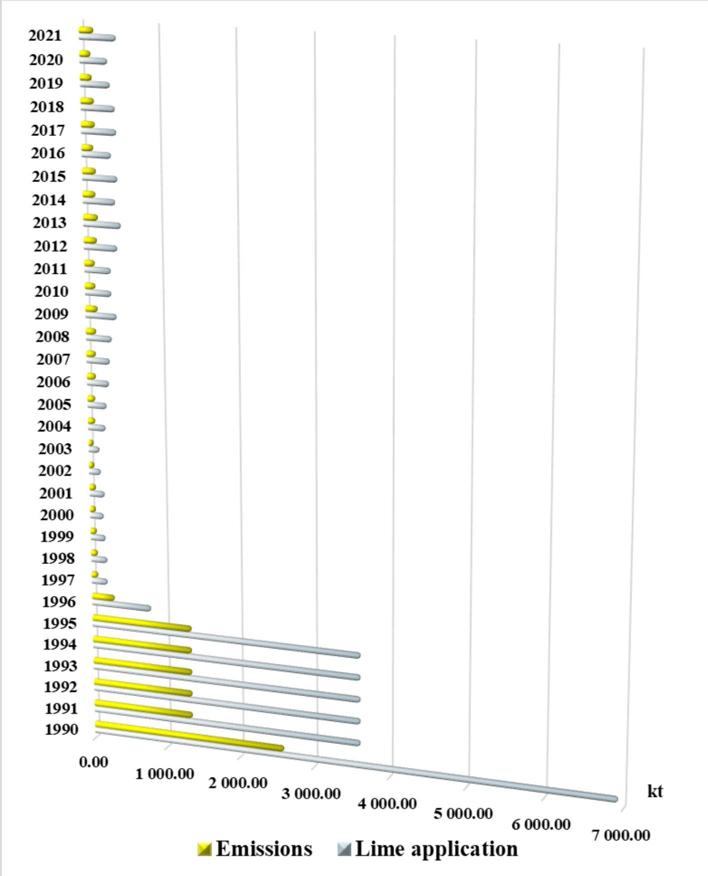


Fig. 5.13. Carbon dioxide emissions from liming of agricultural soils and their dependence on the amount of introduced liming materials

Liming used to reduce soil acidity and improve plant growth in managed systems, in particular on agricultural soils and in managed forests.

In accordance with the letters from National Academy of Agrarian Sciences of Ukraine (№12881/5/20 of 28.08.2020 and №30016/10/21 of 15.07.2021) improving the quality of acidic soils in Ukraine is carried out by their liming with lime fertilizers. The raw materials for the lime fertilizers production are natural limestone rocks and industrial waste.

Natural limestone rocks are represented by hard (limestone, dolomite, chalk) and soft (calcsinter, marl, clay marl, powder dolomite) rocks. Also used products of processing of natural limestone rocks – quicklime and slaked lime.

As a raw for the lime fertilizers production used some kinds of industrial waste, which contain Ca^{+2} and Mg^{+2}, such as defecation dirt, shale and peat ash, cement kiln dust, ets.

5.8.2 Methodological issues

Emissions estimation performed in accordance to Equation 11.12 of the 2006 IPCC Guidelines Tier 1 procedure [1].

The input data that used for the relevant calculations were:

– the annual amount of liming materials (Annex 3.2.6, Table A3.2.6.1);

– the active substance share;

– emission factor.

Sources of data on liming materials (lime fertilizers) that applied to acidic agricultural soils were Statistical bulletin: "The application of synthetic and organic fertilizers for harvest of agricultural crops" [24] and analytical study [2]. For those years where statistics are not available, the interpolation method used. However, national statistics do not collect a data about kinds of liming fertilizers that used for liming acidic agricultural soils (collected data only in full weight of lime materials). So, information about actual kinds of liming fertilizers, their number, which was applied, and content of inert materials in them are not available for all report period.

Two conservative judgments were made according to country specific practices of lime fertilizers application and evaluation of inert materials content in them:

– limestone fertilizers contain not less than 85 % of the active substance [19-20] and this coefficient used for estimation the amount of liming materials in weight of active matter;

– dolomite used as liming material, but its number is insignificant and it is impossible to identify/calculate it.

As the liming is performed by introduction of liming fertilizers that mostly contain $CaCO_3$, it was decided to use the default emission factor from the 2006 IPCC Guidelines to evaluate CO_2 emissions from liming, which is 0.12 [1].

5.8.3 Uncertainty and time-series consistency

The uncertainty assessment performed based on Tier 1 procedure of the 2006 IPCC Guidelines [1]. Table 5.22 shows uncertainties of AD and the EF for category 3.G Liming.

Table 5.22. Uncertainties of reporting year in category 3.G Liming

Category	Uncertainty, %
Amount of liming materials introduced	6
Emission factor	50

Estimation of direct emissions in category 3.G Liming for the entire time series carried out using the same method with the same degree of detail.

5.8.4 Category-specific QA/QC procedures

The general quality control and assurance procedures were applied to estimation of GHG emissions in category 3.G Liming. In 3.G Liming category, a well-correlated link between the AD and GHG emissions can be traced (Fig. 5.13).

5.8.5 Category-specific recalculations

Any recalculations of GHG emissions performed in category 3.G Liming.

5.8.6 Category-specific planned improvements

AD detailing and EF clarification are the main improvements in this category.

5.9 Urea Application (CRF category 3.H)

5.9.1. Category description

Urea (or Carbamide) – $CO(NH_2)_2$ used as nitrogen fertilizer in all soil and climatic zones of Ukraine. It attributed to the group of amide fertilizers and the most concentrated solid nitrogen fertilizer. It characterized by insignificant losses of nitrogen in soil. In soil, the amide form transformed into ammonia one, and then – into the nitrate one, which conditions its use for crops with a long vegetation season.

National characteristics of agricultural practices condition limited use of urea as a nitrogen fertilizer, which makes it possible to apply Tier 1 method (Table 5.23; Annex 3.2.9, Table A3.2.9.5).

After the economic crisis caused by the collapse of the USSR, from 1990 to 1999 there was a decline in the amount of urea used and the related emissions in Ukraine (Fig. 5.14).

Table 5.23. Review of category 3.H Urea Application

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2021	
Urea Application	T 1	D	CO_2	No	270.14	235.60	-12.79

Since 2000, the amount of urea introduced into agricultural soils and, consequently, that of emissions gradually increased and in 2008 exceeded the indicators of the baseline 1990. In 2004 and 2009, the emissions decreased sharply due to unfavorable economic conditions.

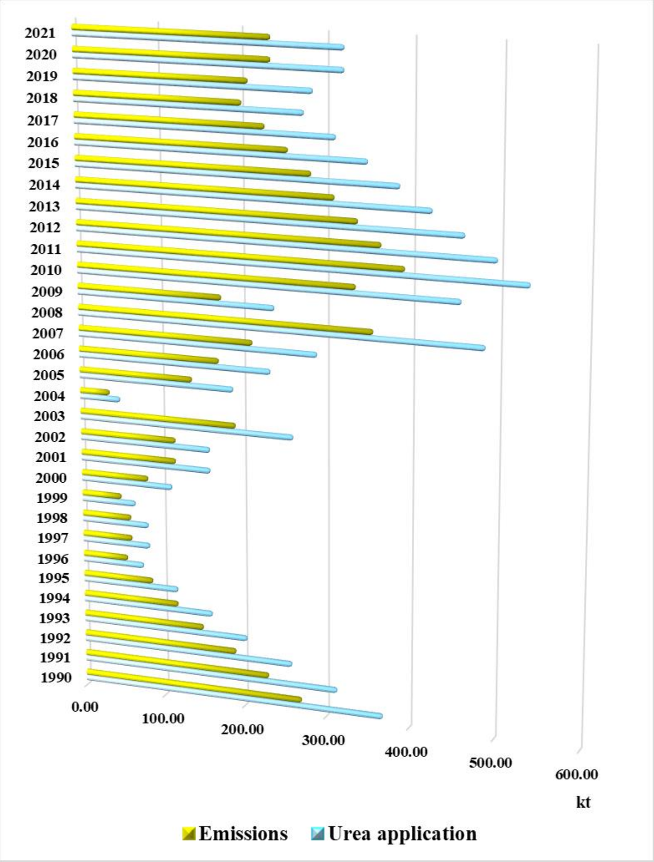


Fig. 5.14. Carbon dioxide emissions from urea application on agricultural soils and their dependence on the amount of introduced urea

5.9.2 Methodological issues

Emissions estimation performed in accordance to Equation 11.13 of the 2006 IPCC Guidelines Tier 1 procedure [1].

The input data that used for the relevant calculations are the annual amount of urea used as fertilizer (Annex 3.2.7, Table A3.2.7.1) and emission factor.

The main sources of data are the SSSU and analytical study [2]. However, SSSU do not collect a data of amount of urea that used as a fertilizer on agricultural soils during the 1990-2017 period (the statistical bulletin "The application of synthetic and organic fertilizers for harvest of agricultural crops" [24] contains this data from 2018). Therefore, alternative sources of data (FAO (http://faostat3.fao.org/download/R/RF/E), conservative judgement) used for AD collection.

AD sources ranged in the next line:

$$Maine\ source \Rightarrow Alternative\ sources$$

or

$$SSSU \Rightarrow FAO \Rightarrow Conservative\ judgement$$

That is why for reporting period AD collected from different sources:

– 1990-2001 – as a share (conservative coefficient according to country specific practice) of the total annual number of the applied N fertilizers;
– 2002-2004 – FAO data;
– 2005-2007 – as a share (conservative coefficient according to country specific practice) of the total annual number of the applied N fertilizers;
– 2008-2011 – FAO data;
– 2012-2017 – interpolation and analytical study [2] (analytical study used since 2014);
– 2018-onwards – SSSU data and analytical study [2].

Analysis of AD sources show that for 1990-2017 used only alternative sources. However, for 1990-2017 period FAO reported data only for 2002-2004 and 2008-2011.

For 1990-2001 and 2005-2007 the data of applied urea calculated as a share of the total annual number of the applied N fertilizers. This factor (a share of the total annual number of the applied N fertilizers) estimated as conservative coefficient according to country specific practice. Small error of the calculated data is a main reason to use this country specific method for estimation an annual number of applied urea for these years. For 2012-2017 an interpolation used to make a linear step from FAO to SSSU data.

SSSU and FAO reported data for 2018-2020, but these sources have a large data difference. However, FAO reported that these data is "Official data from questionnaires and/or national sources and/or COMTRADE (reporters)" that is why it was a conservative solution to use SSSU data. This solution is in line with "AD sources range".

Urea AD include urea that applied as fertilizer on Cropland (for agricultural crops: cereal crops, leguminous crops, industrial crops, roots and tubers, vegetables, food melons, fodder crops and other) and Grassland (hayfields and cultivated pastures).

A default EF from the 2006 IPCC Guidelines to evaluate CO_2 emissions from urea application was used, which is 0.20 [1].

5.9.3 Uncertainty and time-series consistency

The uncertainty assessment performed based on Tier 1 procedure of the 2006 IPCC Guidelines [1]. Table 5.24 shows uncertainties of AD and the EF for category 3.H Urea Application.

Table 5.24. Uncertainties of reporting year in category 3.H Urea Application

Category	Uncertainty, %
Amount of urea applied	6
Emission factor	50

Estimation of CO_2 emissions in category 3.H Urea Application for the entire time series carried out using the same method with the same degree of detail.

5.9.4 Category-specific QA/QC procedures

The general quality control and assurance procedures were applied to estimation of GHG emissions in category 3.H Urea Application.

In 3.H Urea Application category, a well-correlated link between the AD and GHG emissions can be traced (Fig. 5.14).

5.9.5 Category-specific recalculations

Any recalculations of GHG emissions performed in category 3.H Urea Application.

5.9.6 Category-specific planned improvements

SSSU data (data of amount of urea that used as a fertilizer on agricultural soils) accumulation over the following years will provide an opportunity for AD reviewing.

6 LAND USE, LAND-USE CHANGE AND FORESTRY (CRF SECTOR 4)

6.1 Sector Overview

In the sector of land use, land-use change and forestry (LULUCF), not only greenhouse gas emissions are accounted, but also removals in land-use categories in accordance with recommendations of the Guidelines [1]. Throughout the reporting period from 1990 to 2010 and in 2020 (except 2008), the resulting GHG removals were observed in the sector, while in 2011-2019 and in 2021 the sector was a net source (Fig. 6.1).

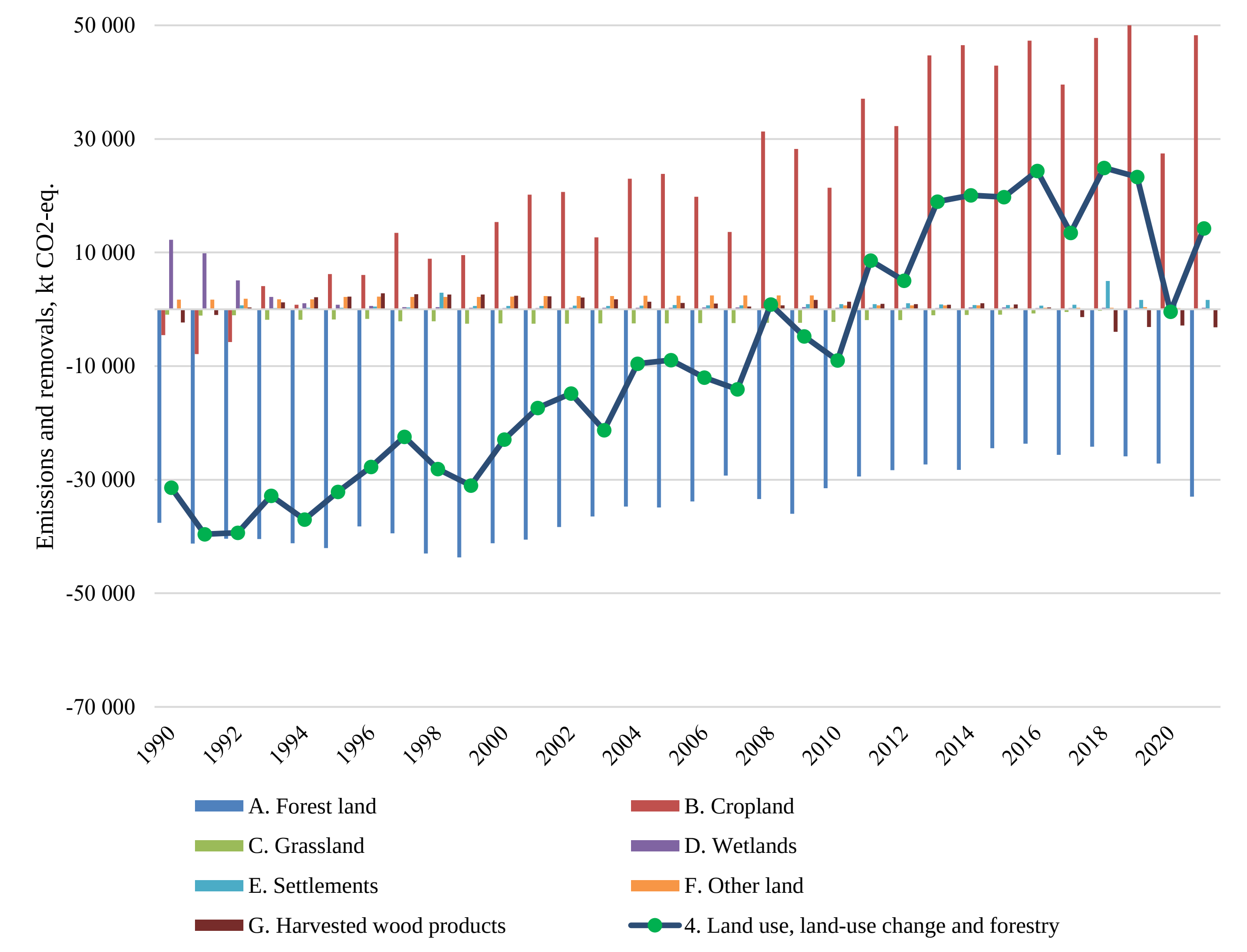


Fig. 6.1 Emissions and removals in the LULUCF sector in Ukraine in 1990-2020

The resulting values for the LULUCF sector vary from -39.6 Mt CO_2-eq. removals in 1991 to -14.2 Mt CO_2-eq. of emissions in 2021 with peak of emissions (24.9 Mt CO_2-eq.) in 2018.

Land-use areas representation in GHG inventory in the LULUCF sector was performed based on Approach 2. Ukraine is currently seeking for possibilities to change activity data gathering procedure and its further processing aiming to address recommendations from the ERT. It was expected to be finalized in 2019 submission however due to technical difficulties and uncertainty of funding this is expected to be finalized later. Current NIR is prepared using previous activity data sources and approaches.

The total area of land use categories in the national statistical reporting form 16-zem was used (previously been called 6-zem) as the source data for area presentation according to IPCC classification. Table 6.3 shows total areas of land-use categories for Ukraine as a whole, which were used in construction of land-use change matrix (Table 6.4).

After subtraction of areas with anthropogenic influence from the totals of corresponding land-use categories of 16-zem statistical form unmanaged areas were derived. In CRF tables for stated land-use categories information regarding areas is presented by components – "managed" and "unmanaged" lands, where it is required by 2006 IPCC Guidelines. Table 6.2 presents detailed information sources and how they were used during the inventory preparation.

In the land-use category Forest Land, a total GHG removal level is 23.7-43.7 Mt CO_2-eq. throughout the time series. Among different factors, which influence the trend, the most significant are:

- intensity of wood harvesting;
- frequency, intensity and the nature of fires and other disturbances of forest stands;
- change in land area converted into this category.

GHG emissions and removals trend in Cropland category varies between -7.9 Mt CO_2-eq. removals in 1991 and 48.3 Mt CO_2-eq. emissions in 2021, although the highest level of emissions in the category was 50.0 Mt CO_2-eq. in 2019.

Significant Cropland category trend changes are caused mostly by CSC in mineral soils from crop grow. Particularly since 1990 there was change from 2.5 Mt C of removals to 12.9 Mt C of emissions totally in mineral soil pool. That change is caused mainly by switch of crops to more soil exhausting with lower rates of organic fertilizers application (fig. 6.2 and 6.3). Moreover, there is a variety in yield of crops harvested between years. More detailed data on AD for Cropland and Grassland categories are provided in the Annex 3.3.2.

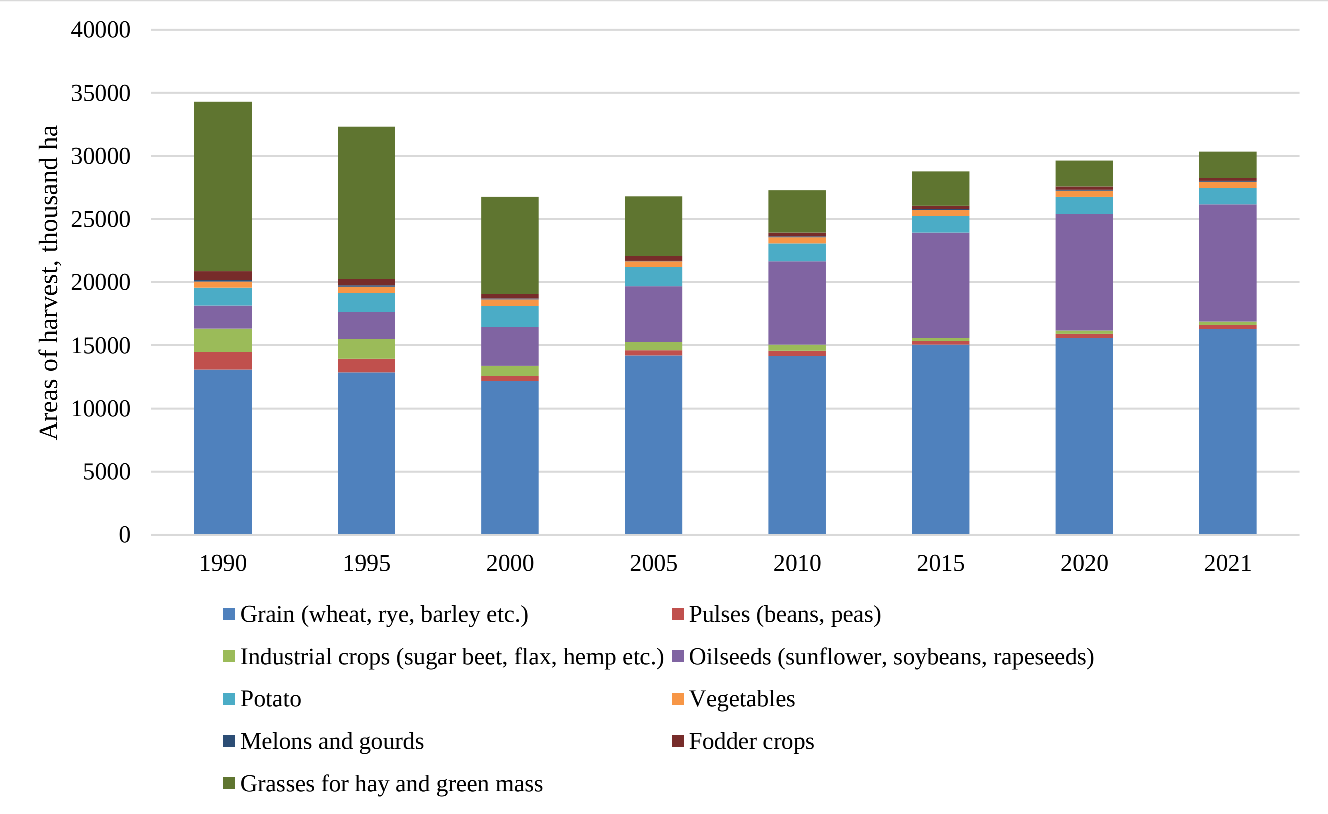


Fig. 6.2. Structure of areas of crops grown on Croplands

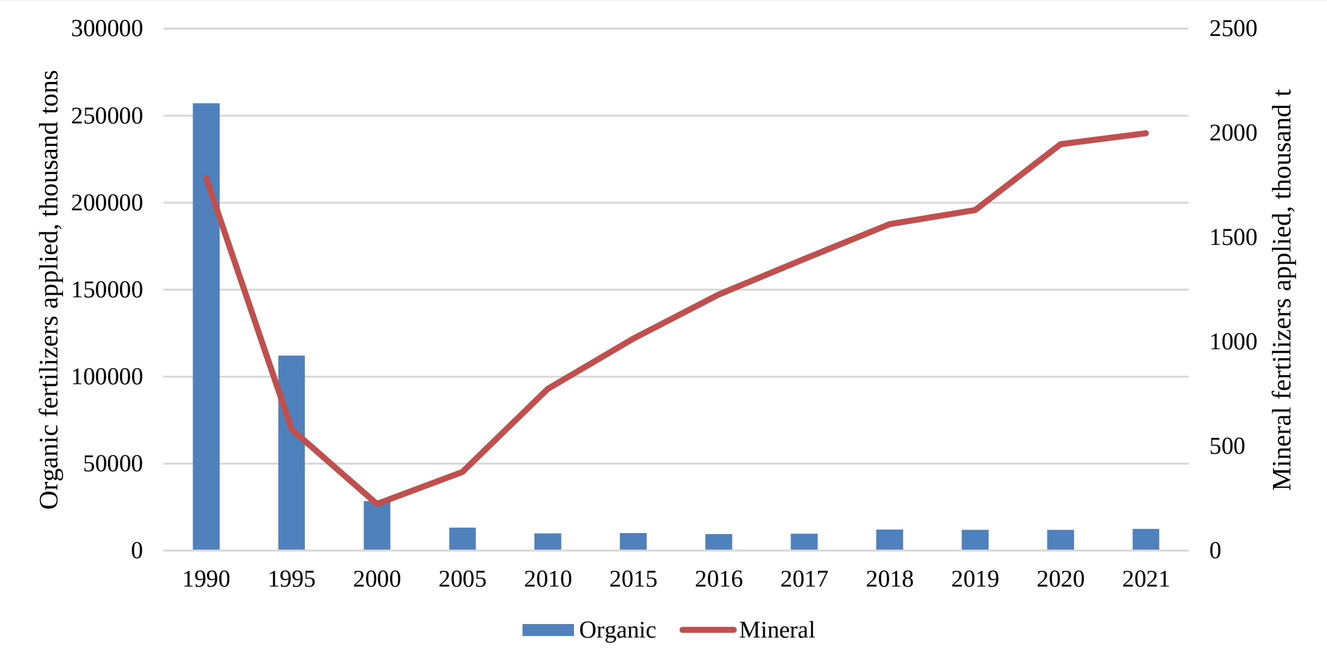


Fig. 6.3. Fertilizers input to Cropland

Grassland category is a net sink for the time series 1990-2018 with 0.9 Mt CO_2-eq. removals in 1990 with increase of removals in 2001-2003 to 2.5 Mt CO_2-eq., and then drop in removals to 0.2 Mt CO_2-eq. in 2018. In 2019-2021 the category became a net source with emissions of 93 kt CO_2-eq. in the most recent year. The most significant reasons for such trend are CSC in mineral soil pool, caused by land-use changes to Grassland category and change in areas and management of pastures and hayfields, as well as dynamics of areas of land conversions to the Grassland.

Throughout the time series since 1990, emissions in the category Wetlands decreased in line with reduction in the area of peat extraction. Significant impact on GHG emissions has peat extraction process. Since 1990 peat extraction areas, as well as amounts of extracted peat for non-energy use, has decreased by several times (Fig. 6.1 and 6.4). Consequently, the drop occurred from 12.3 Mt CO_2-eq. to 0.3 Mt CO_2-eq.

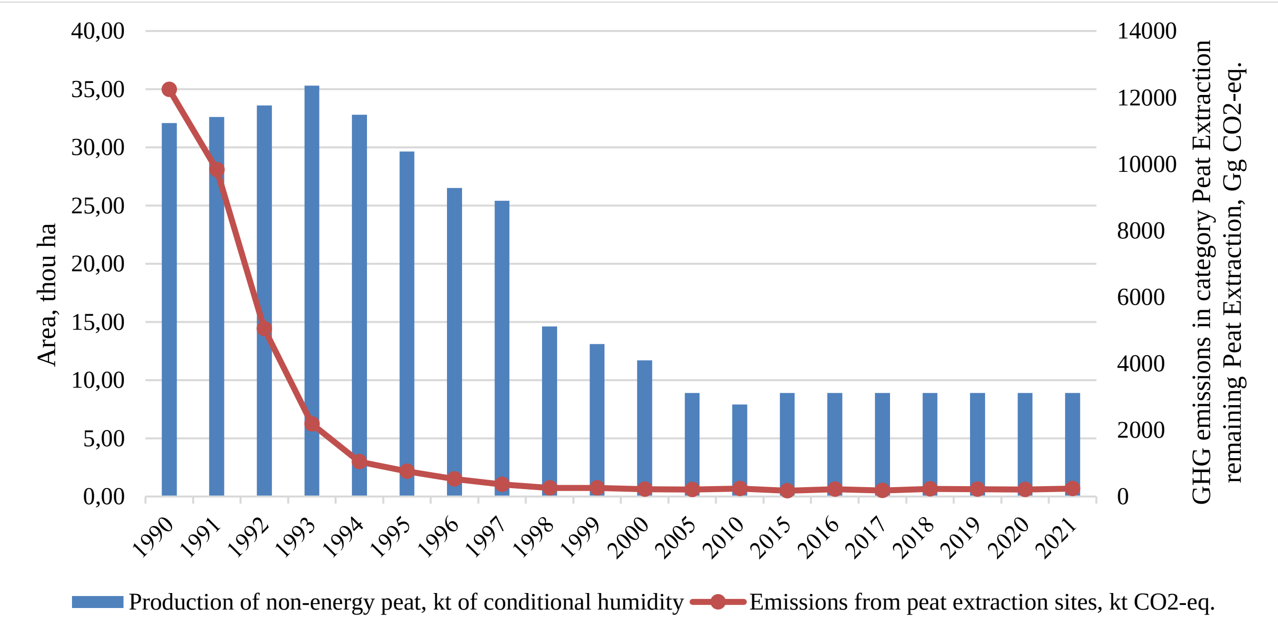


Fig. 6.4 Peat extraction areas and emissions in the category Wetlands

Emissions in categories Settlements and Other Land occur when there are land-use changes only. Due to significance of areas converted there are emissions up to 5.1 Mt CO_2-eq. in 1998 and 5.3 Mt CO_2-eq. in 2018 totally in these categories.

Indirect N_2O emissions were estimated from all land-use categories. In Ukraine those emissions occur in LULUCF sector during conversions between land-use categories.

The share of carbon in harvested wood products (category 4.G) is presented in figure 6.5.

The switch of removals to emissions within the time series is caused by reorientation of industrial roundwood use – from internal use within the country to export, which has grown from around 693 m^3 in 1992 (the earliest available data) to 3.5 million m^3 in 2016. Restriction of export of raw roundwood resulted in export of industrial roundwood as low as 400 m^3 in 2021, while production increased from 4.7 million m^3 in 1997-1999 to 8.2 million m^3 in 2021. Similar trend is observed in sawnwood production: decline by around 66% - from 7.4 million m^3 in 1990 to 1.8 million m^3 in 2014, but then increase to 2.2 million m^3 in 2021.

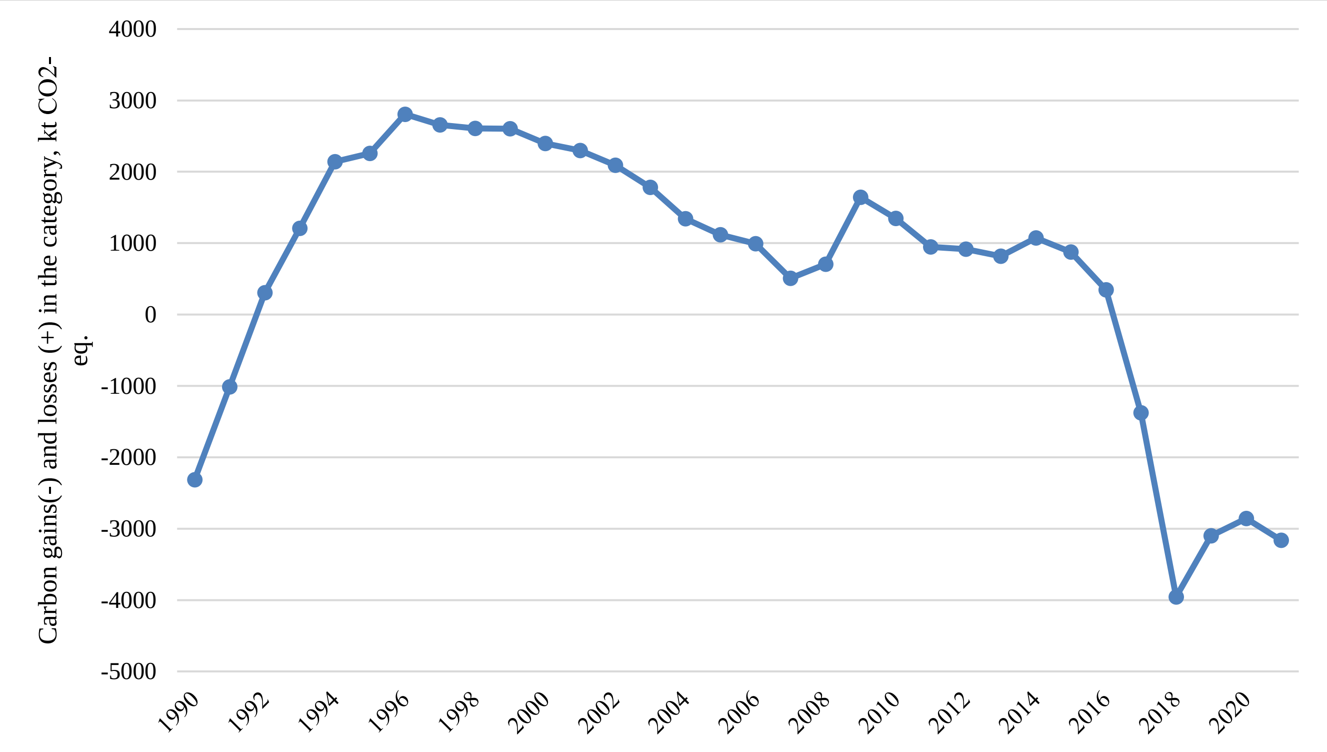


Fig. 6.5 HWP contribution into the total emissions/removals in the LULUCF sector

6.1.1 Land-use change matrix

For the GHG inventory, land-use areas representation is presented using Approach 2 according to IPCC land classification [1]:

1) Forest Land;
2) Cropland;
3) Grassland;
4) Wetlands;
5) Settlements;
6) Other Land.

Current NIR was prepared using approach and data sources as in 2017 submission. Ukraine's efforts on transition to use of remote sensing data is described in chapter 6.1.2 of NIR submitted in 2019. Unfortunately, results had low accuracy and time series consistency to be used as a main source of data for land-use change matrix.

The main source of information for this distribution of land in Ukraine is statistical reporting form No. 16-zem (previously it was 6-zem). Definitions of land-use categories adopted in the national statistical practice [2] and their alignment with those proposed in the methodology [1] are presented in Table 6.1.

It should be noted that every land use category is divided into the two components:

- land constantly remaining in the respective category (i.e. for more than 20 years);

- land converted from one category to another. By default, the land remains in this category for 20 years before moving on to the respective category [1].

Table 6.1. Land systematization in statistical reporting form No.16-zem

Land-use category under 2006 IPCC Guidelines	**Column # in form No. 16-zem**	**Category name**	**Category description**
4.B. Cropland	4	Arable lands	Land systematically cultivated and used for sowing perennial grasses, as well as for bare fallow and greenhouses. "Arable land" does not include hayfields and pastures plowed for the purposes of their radical improvement and constantly used for grass forage crops for mowing hay and grazing, as well as areas between rows of gardens used for sowing
4.B. Cropland	5	Fallow lands	Land previously plowed, and later (for more than a year starting from the autumn) they were not used for planting of agricultural crops and were not prepared for conversion into the "bare fallow" category
4.B. Cropland	9	Perennial crops	Perennial plantations created to produce fruits, berries
4.C. Grassland	7	Hayfields	Agricultural land systematically used for hay mowing, including plots covered with tree and shrub vegetation by 20% or less
4.C. Grassland	8	Pastures	Agricultural land systematically used for grazing, including plots covered with tree and shrub vegetation by 20% or less
4.A. Forest Land	16	Forest areas, covered with woody vegetation	Areas of forest plots, covered by woody and shrub vegetation with crown cover 40% in young stands and 30% in older stands of area.
4.A. Forest Land	17	Forest areas, not covered with woody vegetation	Areas of forest plots, temporarily or permanently not covered by forest vegetation (due to unevenness of landscape, forest management, natural disturbances etc.). It includes recently reforested/afforested areas, nurseries, forest roads, fire breaking open areas, open areas assigned for afforestation/reforestation and other.
4.A. Forest Land	15	Shrubs	Land covered with shrub vegetation
4.E. Settlements	25-42	Lands with buildings, infrastructure, cemeteries and other	All land occupied by industrial facilities, built-up with residential houses, roads, mines, open extraction sites, and any other facilities established for various types of human activities, including the areas for their maintenance
4.D. Wetlands	12, 20-24	Open water	Marshes, lakes, rivers, artificial water bodies etc.
4.F. Other Land	10-11, 13-14	Open land without vegetation or with little vegetation	Land not included into the above categories (rocks, sand, solonchaks, and other land)

Table 6.2. National statistical forms and databases used for GHG inventory in the LULUCF sector

Data source	Content	Category and the way of application
Land-use category Forest Land		
Database	Information on the afforestation, including the main features of species and natural areas, with the geo-coordinate pegging of the sites by forestry enterprises, with cartographic images, as well as characteristics of the anthropogenic component confirmed with documents. Based on use of: • information array of the Ukrainian State Forest Inventory Design Association; • land-use change matrix for definition of the land conversion vector and the share of each of the categories in these conversions, in the national statistical practice this information is not available	4.A, 4.B.2.1, 4.C.2.1, 4.D.2.1, 4.E.2.1, 4.F.2.1. Data on the area, species composition by natural and climatic zones and territorial administrative information
3-lg	"Forest management" (annual). Contains information on amounts of harvesting from forests	4.A.
Land-use categories Cropland and Grassland		
F16-zem	"Report on availability of lands and their distribution by land owners, land users, land plots, and economic activities" (annual). Contains data on the area of territories with anthropogenic activities, which are subject to reporting under the GHG inventory	4.B.1, 4.C.1.
29-sg	"Agricultural crop harvesting" (annual). The data for each of the agricultural crops grown in the reporting year includes: • areas harvested; • gross harvest in weight after processing; • crop yield	4.B.1, 4.C.1.
9-bsg	"Application of mineral and organic fertilizers, gypsum and liming" (annual). The data includes: • amounts of applied nitrogen fertilizers, presented in active substance; • amounts organic fertilizers applied; • amounts of liming	4.B.1, 4.C.1.
Land-use category Wetlands		
F16-zem	"Report on availability of lands and their distribution by land owners, land users, land plots, and economic activities" (annual). Contains totals of land-use category areas considered for the purposes of the balance of the territories, as well as operated peat extraction areas	4.D.1
1-П	"Industrial production in Ukraine". Contains data on peat obtained from peat extraction, which is used in agriculture	4.D.1
Land-use category Settlements and Other Land		
F16-zem	"Report on availability of lands and their distribution by land owners, land users, land plots, and economic activities" (annual). Contains totals of land-use category areas considered for the purposes of the balance of the territories	4.E.1, 4.F.1

Table 6.3. Areas of land-use categories (based on reporting form No. 16-zem), kha

Year	Forests and other forest-covered areas	Agricultural land (except hayfields and pastures)	Hayfields and pastures	Open wetlands and inland waters	Settlements	Open land without vegetation and with special vegetation
1990	10221.5	35847.3	7232.2	3319.1	2420.3	1314.5
1991	10248.2	35731.2	7329.6	3337.3	2409.2	1299.4
1992	10306.6	35897.9	7311.8	3338.0	2308.2	1192.4
1993	10331.0	35706.2	7473.2	3340.4	2386.2	1117.9
1994	10352.2	35639.6	7504.2	3347.8	2403.2	1107.9
1995	10357.8	35605.5	7523.9	3353.5	2312.7	1201.5
1996	10372.0	35478.8	7628.8	3350.7	2334.4	1190.2

Year	Forests and other forest-covered areas	Agricultural land (except hayfields and pastures)	Hayfields and pastures	Open wetlands and inland waters	Settlements	Open land without vegetation and with special vegetation
1997	10380.2	35328.6	7773.0	3355.4	2336.9	1180.8
1998	10397.6	35277.9	7789.6	3372.2	2442.0	1075.6
1999	10403.3	35229.1	7838.1	3372.2	2457.4	1054.8
2000	10413.6	35147.9	7910.0	3370.7	2456.2	1056.5
2001	10426.2	35115.2	7924.4	3374.2	2449.4	1065.5
2002	10438.9	35083.6	7938.8	3372.8	2463.0	1057.8
2003	10457.5	35040.5	7968.4	3374.0	2459.3	1055.2
2004	10475.9	35017.7	7968.2	3378.2	2458.3	1056.6
2005	10503.7	34992.1	7950.6	3382.9	2467.5	1058.1
2006	10539.9	34954.7	7938.9	3391.1	2470.2	1060.1
2007	10556.3	34935.5	7933.5	3397.4	2476.6	1055.6
2008	10570.1	34926.8	7918.1	3400.5	2489.0	1050.4
2009	10591.9	34914.2	7899.6	3402.6	2499.1	1047.5
2010	10601.1	34899.0	7892.9	3403.4	2512.5	1046.0
2011	10611.3	34890.9	7886.0	3402.9	2523.2	1040.6
2012	10621.4	34885.9	7870.1	3403.1	2535.2	1039.2
2013	10624.4	34888.9	7855.6	3404.5	2542.6	1038.9
2014	10630.3	34883.2	7848.3	3409.0	2550.4	1033.7
2015	10633.1	34885.9	7840.5	3408.7	2552.9	1033.8
2016	10663.8	34875.3	7833.8	3408.7	2561.6	1011.8
2017	10675.0	34869.6	7820.9	3408.7	2577.6	1003.2
2018	10685.6	34952.0	7577.0	3406.7	2827.7	905.9
2019	10686.8	34977.3	7534.2	3398.1	2858.4	900.1
2020	10689.3	34987.1	7506.3	3398.1	2881.9	892.2
2021	10692.5	34996.9	7478.4	3398.1	2905.3	883.8

The national statistical system currently does not reflect the actual change in land-use categories and the nature of the change of management practices for the lands that are part of the land-use categories. Therefore, the conservative decision was made to assume that the difference between category areas in the accounting year and in the previous year is the area that was converted from one category into another. Thus, it is distributed among the categories that increased in size, proportionally to the area increase. For activities related to deforestation or afforestation, actual data from the database was used. The aggregated land-use change matrix is shown in Table 6.4.

Since 2010, the lands in the subcategories of "converted" that were converted in 1990 are included into the respective subcategories of "remaining", maintaining the conversion period proposed by the IPCC - 20 years.

Table 6.4. The land-use change matrix with cumulative approach between categories for the time series of 1990-2021, kha

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
1990							
Forest Land	10 211.94	0.04	0.01	0.00	0.08	0.01	10 212.08
Cropland	9.55	35 847.26	194.23			100.16	36 151.21
Grassland			7 037.96				7 037.96
Wetlands				3 319.10			3 319.10
Settlements					2 420.22		2 420.22
Other Land						1 214.33	1 214.33
Total	10 221.50	35 847.30	7 232.20	3 319.10	2 420.30	1 314.50	60 354.90
1991							
Forest Land	10 230.85	0.14	0.02	0.00	0.28	0.04	10 231.33
Cropland	15.92	35 731.06	273.70	14.85		100.16	36 135.69
Grassland			7 037.94				7 037.94
Wetlands				3 319.10			3 319.10
Settlements	0.61		7.60	1.42	2 408.92		2 418.55
Other Land	0.83		10.34	1.93		1 199.19	1 212.29
Total	10 248.20	35 731.20	7 329.60	3 337.30	2 409.20	1 299.40	60 354.90
1992							
Forest Land	10 282.73	2.94	0.50	0.04	5.98	0.93	10 293.11
Cropland	15.92	35 728.26	273.70	14.85		100.16	36 132.89
Grassland	0.51	13.14	7 019.67	0.06			7 033.38
Wetlands				3 319.06			3 319.06
Settlements	3.52	74.56	7.60	1.73	2 302.22		2 389.64
Other Land	3.92	78.99	10.34	2.26		1 091.31	1 186.82
Total	10 306.60	35 897.90	7 311.80	3 338.00	2 308.20	1 192.40	60 354.90
1993							
Forest Land	10 299.97	2.94	0.54	0.04	6.00	0.93	10 310.42
Cropland	21.08	35 536.56	389.93	16.58	56.17	100.16	36 120.47
Grassland	0.51	13.14	7 019.63	0.06			7 033.34
Wetlands				3 319.06			3 319.06
Settlements	3.52	74.56	7.60	1.73	2 302.20		2 389.62
Other Land	5.92	78.99	55.51	2.93	21.83	1 016.81	1 181.99
Total	10 331.00	35 706.20	7 473.20	3 340.40	2 386.20	1 117.90	60 354.90
1994							
Forest Land	10 314.62	2.95	0.54	0.04	6.01	0.93	10 325.09
Cropland	26.77	35 469.95	416.88	23.01	70.95	100.16	36 107.73
Grassland	0.51	13.14	7 019.63	0.06			7 033.34
Wetlands				3 319.06			3 319.06
Settlements	3.52	74.56	7.60	1.73	2 302.19		2 389.60
Other Land	6.78	78.99	59.55	3.90	24.05	1 006.81	1 180.08
Total	10 352.20	35 639.60	7 504.20	3 347.80	2 403.20	1 107.90	60 354.90
1995							
Forest Land	10 312.69	2.96	0.55	0.06	6.03	0.98	10 323.27
Cropland	28.83	35 435.84	422.27	24.57	70.95	125.78	36 108.24
Grassland	0.51	13.14	7 019.61	0.06			7 033.32
Wetlands				3 319.04			3 319.04
Settlements	8.99	74.56	21.91	5.87	2 211.67	67.98	2 390.99
Other Land	6.78	78.99	59.55	3.90	24.05	1 006.76	1 180.03
Total	10 357.80	35 605.50	7 523.90	3 353.50	2 312.70	1 201.50	60 354.90
1996							
Forest Land	10 317.84	3.07	2.32	0.22	7.48	1.49	10 317.84
Cropland	36.97	35 309.03	516.67	24.57	90.48	125.78	36.97
Grassland	0.51	13.14	7 017.84	0.06			0.51
Wetlands	0.18		2.09	3 316.08	0.43		0.18

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
Settlements	8.99	74.56	21.91	5.87	2 210.22	67.98	8.99
Other Land	7.50	78.99	67.97	3.90	25.79	994.95	7.50
Total	10 372.00	35 478.80	7 628.80	3 350.70	2 334.40	1 190.20	60 354.90
1997							
Forest Land	10 318.63	3.09	2.35	0.22	7.48	1.52	10 318.63
Cropland	43.94	35 158.81	652.38	28.99	92.83	125.78	43.94
Grassland	0.51	13.14	7 017.82	0.06			0.51
Wetlands	0.18		2.09	3 316.08	0.43		0.18
Settlements	8.99	74.56	21.91	5.87	2 210.22	67.98	8.99
Other Land	7.94	78.99	76.46	4.18	25.94	985.51	7.94
Total	10 380.20	35 328.60	7 773.00	3 355.40	2 336.90	1 180.80	60 354.90
1998							
Forest Land	10 331.65	3.09	3.75	2.63	27.51	1.52	10 370.16
Cropland	45.37	35 108.11	657.77	34.46	127.01	125.78	36 098.50
Grassland	0.51	13.14	7 016.42	0.06			7 030.13
Wetlands	0.18		2.09	3 313.67	0.43		3 316.37
Settlements	8.99	74.56	21.91	5.87	2 190.19	67.98	2 369.51
Other Land	10.89	78.99	87.67	15.51	96.86	880.31	1 170.24
Total	10 397.60	35 277.90	7 789.60	3 372.20	2 442.00	1 075.60	60 354.90
1999							
Forest Land	10 333.10	3.09	3.77	2.65	27.53	1.52	10 371.66
Cropland	48.35	35 059.31	691.78	34.46	137.81	125.78	36 097.48
Grassland	0.51	13.14	7 016.40	0.06			7 030.11
Wetlands	0.18		2.09	3 313.65	0.43		3 316.35
Settlements	8.99	74.56	21.91	5.87	2 190.17	67.98	2 369.49
Other Land	12.16	78.99	102.16	15.51	101.46	859.51	1 169.81
Total	10 403.30	35 229.10	7 838.10	3 372.20	2 457.40	1 054.80	60 354.90
2000							
Forest Land	10 338.40	3.11	3.90	2.65	27.53	1.62	10 377.21
Cropland	53.19	34 978.09	761.37	34.46	137.81	127.42	36 092.34
Grassland	0.51	13.14	7 016.27	0.06			7 029.98
Wetlands	0.27		3.37	3 312.15	0.43	0.03	3 316.25
Settlements	9.07	74.56	22.93	5.87	2 188.97	68.01	2 369.42
Other Land	12.16	78.99	102.16	15.51	101.46	859.42	1 169.71
Total	10 413.60	35 147.90	7 910.00	3 370.70	2 456.20	1 056.50	60 354.90
2001							
Forest Land	10 345.95	3.16	3.98	2.66	27.56	1.65	10 384.96
Cropland	57.37	34 945.34	773.29	37.36	137.81	134.87	36 086.04
Grassland	0.51	13.14	7 016.19	0.06			7 029.90
Wetlands	0.27		3.37	3 312.14	0.43	0.03	3 316.24
Settlements	9.94	74.56	25.41	6.48	2 182.14	69.56	2 368.08
Other Land	12.16	78.99	102.16	15.51	101.46	859.38	1 169.68
Total	10 426.20	35 115.20	7 924.40	3 374.20	2 449.40	1 065.50	60 354.90
2002							
Forest Land	10 351.79	3.16	4.17	2.67	27.96	1.65	10 391.40
Cropland	62.70	34 913.74	784.47	37.36	148.37	134.87	36 081.50
Grassland	0.51	13.14	7 016.00	0.06			7 029.71
Wetlands	0.51		3.87	3 310.73	0.90	0.03	3 316.04
Settlements	9.94	74.56	25.41	6.48	2 181.74	69.56	2 367.69
Other Land	13.46	78.99	104.88	15.51	104.03	851.68	1 168.57
Total	10 438.90	35 083.60	7 938.80	3 372.80	2 463.00	1 057.80	60 354.90
2003							
Forest Land	10 365.21	3.26	4.17	2.73	27.96	1.73	10 405.06
Cropland	67.21	34 870.54	810.29	38.40	148.37	134.87	36 069.69
Grassland	0.51	13.14	7 016.00	0.06			7 029.71

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
Wetlands	0.51		3.87	3 310.67	0.90	0.03	3 315.97
Settlements	10.32	74.56	27.63	6.57	2 178.04	69.56	2 366.68
Other Land	13.73	78.99	106.44	15.58	104.03	849.01	1 167.79
Total	10 457.50	35 040.50	7 968.40	3 374.00	2 459.30	1 055.20	60 354.90
2004							
Forest Land	10 376.16	3.85	4.17	2.73	28.21	1.83	10 416.96
Cropland	74.29	34 847.15	810.29	42.39	148.37	136.20	36 058.69
Grassland	0.58	13.14	7 015.80	0.09		0.01	7 029.62
Wetlands	0.51		3.87	3 310.67	0.90	0.03	3 315.97
Settlements	10.63	74.56	27.63	6.74	2 176.79	69.62	2 365.97
Other Land	13.73	78.99	106.44	15.58	104.03	848.91	1 167.69
Total	10 475.90	35 017.70	7 968.20	3 378.20	2 458.30	1 056.60	60 354.90
2005							
Forest Land	10 396.29	3.86	4.19	2.75	28.29	1.83	10 437.21
Cropland	78.84	34 821.54	810.29	45.18	153.82	137.09	36 046.76
Grassland	3.70	13.14	6 998.17	2.00	3.75	0.62	7 021.39
Wetlands	0.51		3.87	3 310.65	0.90	0.03	3 315.96
Settlements	10.63	74.56	27.63	6.74	2 176.71	69.62	2 365.89
Other Land	13.73	78.99	106.44	15.58	104.03	848.91	1 167.69
Total	10 503.70	34 992.10	7 950.60	3 382.90	2 467.50	1 058.10	60 354.90
2006							
Forest Land	10 411.90	3.86	4.27	2.75	28.37	1.86	10 453.01
Cropland	94.52	34 784.14	810.29	51.42	155.88	138.62	36 034.86
Grassland	8.61	13.14	6 986.40	3.96	4.39	1.10	7 017.60
Wetlands	0.51		3.87	3 310.65	0.90	0.03	3 315.96
Settlements	10.63	74.56	27.63	6.74	2 176.63	69.62	2 365.81
Other Land	13.73	78.99	106.44	15.58	104.03	848.88	1 167.66
Total	10 539.90	34 954.70	7 938.90	3 391.10	2 470.20	1 060.10	60 354.90
2007							
Forest Land	10 403.65	3.86	4.28	2.86	28.46	2.01	10 445.12
Cropland	110.78	34 764.94	810.29	55.58	160.10	138.62	36 040.31
Grassland	13.18	13.14	6 980.99	5.13	5.58	1.10	7 019.12
Wetlands	0.51		3.87	3 310.54	0.90	0.03	3 315.84
Settlements	10.63	74.56	27.63	6.74	2 176.54	69.62	2 365.73
Other Land	17.55	78.99	106.44	16.55	105.02	844.23	1 168.79
Total	10 556.30	34 935.50	7 933.50	3 397.40	2 476.60	1 055.60	60 354.90
2008							
Forest Land	10 389.16	3.86	4.28	2.86	36.41	2.01	10 438.58
Cropland	119.18	34 756.24	810.29	56.50	163.78	138.62	36 044.61
Grassland	28.05	13.14	6 965.59	6.76	12.10	1.10	7 026.74
Wetlands	0.51		3.87	3 310.54	0.90	0.03	3 315.84
Settlements	10.63	74.56	27.63	6.74	2 168.59	69.62	2 357.78
Other Land	22.57	78.99	106.44	17.10	107.22	839.03	1 171.36
Total	10 570.10	34 926.80	7 918.10	3 400.50	2 489.00	1 050.40	60 354.90
2009							
Forest Land	10 373.12	3.87	4.28	2.86	36.43	2.01	10 422.57
Cropland	133.20	34 743.63	810.29	57.28	167.52	138.62	36 050.55
Grassland	48.64	13.14	6 947.09	7.90	17.59	1.10	7 035.47
Wetlands	0.51		3.87	3 310.54	0.90	0.03	3 315.84
Settlements	10.63	74.56	27.63	6.74	2 168.57	69.62	2 357.76
Other Land	25.79	78.99	106.44	17.28	108.09	836.13	1 172.72
Total	10 591.90	34 914.20	7 899.60	3 402.60	2 499.10	1 047.50	60 354.90
2010							
Forest Land	10 368.56	3.83	4.27	2.86	36.35	2.00	10 417.86
Cropland	138.80	34 728.47	616.06	57.80	176.23	38.45	35 755.81

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
Grassland	55.32	13.14	7 134.63	8.13	21.43	1.10	7 233.75
Wetlands	0.51	0.00	3.87	3 310.54	0.90	0.03	3 315.84
Settlements	10.63	74.56	27.63	6.74	2 168.65	69.62	2 357.84
Other Land	27.29	78.99	106.44	17.33	108.94	934.80	1 273.80
Total	10 601.100	34 899.00	7 892.90	3 403.40	2 512.50	1 046.00	60 354.90
2011							
Forest Land	10 364.12	3.73	4.25	2.86	36.25	1.97	10 413.18
Cropland	141.41	34 720.47	536.60	42.95	180.33	38.46	35 660.21
Grassland	62.72	13.14	7 225.15	8.13	24.93	1.10	7 335.17
Wetlands	0.51	0.00	3.87	3 328.24	1.20	0.03	3 333.84
Settlements	10.03	74.56	20.03	5.32	2 168.85	69.62	2 348.41
Other Land	32.52	78.99	96.11	15.40	111.64	929.43	1 264.09
Total	10 611.30	34 890.90	7 886.00	3 402.90	2 523.20	1 040.60	60 354.90
2012							
Forest Land	10 362.35	0.93	3.77	2.83	30.94	1.09	10 401.91
Cropland	145.52	34 884.97	536.60	43.00	183.02	38.46	35 831.56
Grassland	75.31	0.00	7 209.73	8.21	33.49	1.10	7 327.84
Wetlands	0.51	0.00	3.87	3 328.98	1.20	0.03	3 334.59
Settlements	7.11	0.00	20.03	5.01	2 174.15	69.62	2 275.92
Other Land	30.60	0.00	96.11	15.07	112.40	928.91	1 183.09
Total	10 621.40	34 885.90	7 870.10	3 403.10	2 535.20	1 039.20	60 354.90
2013							
Forest Land	10 358.62	0.93	3.73	2.82	31.01	1.08	10 398.19
Cropland	140.37	34 884.97	420.37	41.27	126.85	38.46	35 652.28
Grassland	88.93	2.94	7 356.66	9.59	40.65	1.10	7 499.87
Wetlands	0.51	0.00	3.87	3 331.39	1.20	0.03	3 336.99
Settlements	7.11	0.00	20.03	5.01	2 252.17	69.62	2 353.94
Other Land	28.87	0.06	50.94	14.43	90.72	928.62	1 113.64
Total	10 624.40	34 888.90	7 855.60	3 404.50	2 542.60	1 038.90	60 354.90
2014							
Forest Land	10 365.83	0.92	3.73	2.82	31.00	1.12	10 405.42
Cropland	136.31	34 879.28	393.41	36.25	114.51	38.46	35 598.21
Grassland	91.03	2.94	7 380.36	11.39	43.78	1.10	7 530.60
Wetlands	0.51	0.00	3.87	3 338.79	1.20	0.03	3 344.39
Settlements	7.11	0.00	20.03	5.01	2 269.19	69.62	2 370.95
Other Land	29.51	0.06	46.89	14.75	90.73	923.38	1 105.33
Total	10 630.30	34 883.20	7 848.30	3 409.00	2 550.40	1 033.70	60 354.90
2015							
Forest Land	10 373.36	0.91	3.72	2.80	30.98	1.09	10 412.86
Cropland	134.25	34 879.29	388.02	34.69	114.51	12.84	35 563.60
Grassland	93.73	5.54	7 392.28	11.39	46.18	1.20	7 550.32
Wetlands	0.61	0.10	3.87	3 344.21	1.29	0.03	3 350.11
Settlements	1.64	0.00	5.72	0.87	2 269.20	1.63	2 279.07
Other Land	29.51	0.06	46.89	14.75	90.73	1 017.00	1 198.95
Total	10 633.10	34 885.90	7 840.50	3 408.70	2 552.90	1 033.80	60 354.90
2016							
Forest Land	10 382.40	0.80	1.95	2.64	29.53	0.61	10 382.40
Cropland	134.40	34 868.78	293.63	34.69	97.32	12.84	134.40
Grassland	98.98	5.54	7 492.21	11.39	47.67	1.20	98.98
Wetlands	0.43	0.10	1.78	3 344.37	0.86	0.03	0.43
Settlements	1.64	0.00	5.72	0.87	2 292.35	1.63	1.64
Other Land	45.95	0.06	38.47	14.75	93.84	995.48	45.95
Total	10 663.80	34 875.27	7 833.76	3 408.70	2 561.57	1 011.79	60 354.90
2017							
Forest Land	10 389.81	0.78	1.92	2.64	29.53	0.61	10 425.30

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
Cropland	129.77	34 863.07	157.92	30.26	98.35	12.84	35 292.21
Grassland	104.27	5.54	7 623.53	11.39	55.29	1.20	7 801.21
Wetlands	0.43	0.10	1.78	3 349.07	0.86	0.03	3 352.27
Settlements	1.64	0.00	5.72	0.87	2 294.85	1.63	2 304.71
Other Land	49.02	0.06	29.98	14.47	98.74	986.92	1 179.20
Total	10 674.95	34 869.55	7 820.85	3 408.70	2 577.62	1 003.23	60 354.90
2018							
Forest Land	10 394.19	0.78	0.53	0.23	9.50	0.62	10 405.85
Cropland	128.35	34 863.07	152.52	24.80	64.17	12.84	35 245.74
Grassland	111.82	64.12	7 397.67	11.39	233.01	1.20	7 819.21
Wetlands	0.49	0.57	1.78	3 366.32	2.29	0.03	3 371.48
Settlements	1.64	0.00	5.72	0.87	2 419.98	1.63	2 429.85
Other Land	49.08	23.43	18.78	3.13	98.72	889.63	1 082.77
Total	10 685.56	34 951.97	7 577.00	3 406.74	2 827.67	905.95	60 354.90
2019							
Forest Land	10 397.04	0.78	0.50	0.22	9.48	0.90	10 408.93
Cropland	125.36	34 863.07	118.51	24.80	53.37	12.84	35 197.96
Grassland	113.79	83.04	7 403.35	11.39	256.02	1.20	7 868.78
Wetlands	0.89	4.39	1.78	3 357.69	6.93	0.03	3 371.71
Settlements	1.64	0.00	5.72	0.87	2 435.40	1.63	2 445.26
Other Land	48.08	26.00	4.28	3.13	97.24	883.53	1 062.26
Total	10 686.79	34 977.27	7 534.15	3 398.10	2 858.44	900.14	60 354.90
2020							
Forest Land	10 402.05	0.76	0.37	0.21	9.49	0.82	10 413.70
Cropland	120.52	34 863.09	48.93	24.80	53.37	11.19	35 121.90
Grassland	115.77	90.68	7 447.50	11.39	274.28	1.20	7 940.81
Wetlands	0.80	4.39	0.50	3 357.70	6.93	0.00	3 370.31
Settlements	1.57	0.00	4.70	0.87	2 435.39	1.61	2 444.13
Other Land	48.63	28.15	4.28	3.13	102.39	877.46	1 064.05
Total	10 689.33	34 987.06	7 506.27	3 398.10	2 881.85	892.28	60 354.90
2021							
Forest Land	10 407.10	0.71	0.30	0.20	9.47	0.79	10 418.56
Cropland	116.34	34 863.14	37.01	21.90	53.37	3.74	35 095.50
Grassland	118.22	98.17	7 434.09	11.39	292.21	1.20	7 955.29
Wetlands	0.80	4.39	0.50	3 361.21	6.93	0.00	3 373.82
Settlements	0.70	0.00	2.22	0.26	2 435.42	0.06	2 438.65
Other Land	49.39	30.44	4.28	3.13	107.87	877.96	1 073.08
Total	10 692.54	34 996.85	7 478.39	3 398.10	2 905.26	883.75	60 354.90

6.2 Forest Land (CRF category 4.A)

6.2.1 Category description

In line with the Forest Code of Ukraine [3], the forest is the type of a natural complex that consists mainly of tree and shrub vegetation with the respective soils, herbaceous vegetation, fauna, microorganisms, and other natural ingredients, which are interconnected in their development, influence each other and the environment.

The Forest Land considered for the calculations include plots with the minimal area of 0.1 hectares, minimum width of 20 meters, minimum crown coverage (or the equivalent of stand density) of 30%, and minimum tree height at maturity - 5 meters. The young natural forests and forest plantations that have not reached 30 % of crown coverage (the equivalent of stand density - 0.3) and/or the height of 5 meters are considered a part of forests temporarily not covered with forest vegetation as a result of human activities or environmental factors, but that will reach the threshold values in the future. Inclusion of the minimum value of the forest width (20 m) is consistent with the definition of forests recommended for reporting to the Food and Agriculture Organization of the United Nations (the FAO) and preparation of Ukraine's report [4].

This category is divided into the subcategories – 4.A.1 Forest Land Remaining Forest Land and 4.A.2 Land Converted to Forest Land. The period of transition from the sub-category of converted land to sub-category 4.A.1 is the default – 20 years.

Besides, the subcategory Forest Land Remaining Forest Land is divided into managed and unmanaged forests. The work to revise areas of managed and unmanaged forests is ongoing, as part of land-use transition matrix revision and revision of activity data regarding forestry on time series.

Managed forests include all forest land, on which anthropogenic activities of forest harvesting, forest planting, and forest maintenance are conducted.

Unmanaged Forest land includes lands defined by the Forest Code of Ukraine as "natural forests", "primary forests" and "quasi-primary forests" [3]. These definitions are presented as following:

- "natural forests" (natural forest ecosystems) – forests (forest ecosystems), where locally and temporary anthropogenic influence has occurred, but it did not changed cenotic structure of phytocenosis and thus natural forest ecosystems are able to regenerate (recover) naturally in a short time period to primary forest ecosystems conditions;
- "primary forests" (primary forest ecosystems) – ancient forest (natural forest ecosystems) formed naturally and during its development did not have direct anthropogenic influence;
- "quasi-primary forests" – relatively primary forest ecosystems, where insignificant temporary anthropogenic influence occurred, which has not changed natural structure of stands and with its cease natural conditions of ecosystems are fully recovered during short period of time.

These amendments to Forest Code of Ukraine were introduced in May 2017. The Order of Ministry of Ecology and Natural Resources of Ukraine №161 from 18.05.2018 has defined the methodology for recognition of forests to be natural, primary or quasi-primary as defined by Forest Code of Ukraine.

The data about areas of natural, primary or quasi-primary forests have been received from the Ministry of Defense of Ukraine and the State Agency of Ukraine on Exclusion Zone Management with total area of 1784.2. The State Forest Agency of Ukraine provided information, that under its responsibility there are 29 619.3 ha of such forests. These areas were excluded from the calculation of CSC in Forest land category. Unless the forests are confirmed to be unmanaged, the rest of the Forest land is considered to be managed.

Annually there are 23.7-43.7 kt CO_2-eq. of GHG removed by the Forest Land category in total (Fig. 6.1). In 2021 Forest Land category is a sink of -33.0 Mt CO_2-eq., what is lower by 12 % as in 1990 (-37.6 Mt CO_2-eq.) and higher by 22 % as in 2020 (-27.1 Mt CO_2-eq.).

Difference in C-removals during the reporting period is due to the harvesting volumes, emissions from fires and other disturbances, afforestation areas, as well as conversions to the category from other land-uses.

Emissions of greenhouse gases other than CO_2 are associated with uncontrolled fires and soil drainage, as well as nitrogen mineralization due to land conversion (direct and indirect emissions of Nitrogen). No other activities that contribute into emission of gases other than CO_2 are conducted in Ukraine in the forestry sector (fertilizers, controlled fires).

6.2.2 Methodological issues

The total area of forests is taken from the data of the State Service of Ukraine for Geodesy, Cartography and Cadastre (form 16-zem). The mentioned form also contains data on areas actually covered with forest vegetation at particular year.

Calculations in the Forest Land category were carried out for all pools, except for DOM and mineral soil in sub-category 4.A.1 Forest Land remaining Forest Land. The assumption anticipates zero carbon stock change in forest soils and is based on findings of the research held in Ukraine [5]. Acknowledging need to apply Tier 2 method for both DOM and soil pools Ukraine however unable to apply it due to absence of national specific factors. A work to develop national specific factors is included into improvement plan (please see Annex 8.2).

Changes in the carbon amount in biomass were calculated under Tier 2 using national EFs. For DOM, organic and mineral soils, default factors were used for sub-category 4.A.2 Lands converted to Forest Land. Calculation details and factors are presented in the Annex 3.3.1.

The key sources of activity data (areas of forests by main forest species, grouped by age and region) for the estimations are reporting form on land use, statistic data from the State Statistic Service of Ukraine, forest inventory data, as well as other data of the State Forest Resources Agency of Ukraine. Should be noticed that national statistical data was corrected for 2014-2021 with use of analytical study results [4].

Forest inventory in Ukraine does not yet cover entire forests of the country. The system of forest inventories left from soviet times, when every forest enterprise should have a development plan (previously for 10 years), written by a special institution based on field measurements of temporary plots. The State Forest Resources Agency of Ukraine maintain the same approach for its enterprises. All the rest of forest enterprises (under responsibility of other agencies and ministries) are encouraged to do the same, but not obliged.

Consequently, the data collected during the development of development plans for enterprises were consolidated in the databases, maintained by the Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt". These databases are used to export data on areas, which then are extrapolated to entire area of forest in Ukraine. Currently the data from 1988, 1996 and 2002 inventories were extracted from paper copies of inventory materials. There are electronic databases available for years starting from 2005.

The information from paper copies of forest inventories has other than 10-years subdivision of areas of forests, which is used for data extraction from databases starting from 2005. It is based on age of "maturity" of forests (I class young stands, II class young stands, middle-aged, pre-mature, mature and old stands), commonly used in Ukraine, and depends on forest species, natural zone and protection status of forest plot. So, for example, age of mature pine stand in exploitable forest in flat area of Ukraine will have different age, then mature pine stand in protected area in Carpathian Mountains. This creates a necessity to adjust the data for 1988, 1996 and 2002 years.

The approach used in the submissions before 2022 to adjust the data resulted in rapid shift of C-gains between 2002 and 2005, recognized by the ERT. In the later submission additional data were collected to adjust available data from 1988, 1996 and 2002. Nevertheless, even after the adjustment the data of 2002 was seen as an outlier (blue line on fig. 6.6).

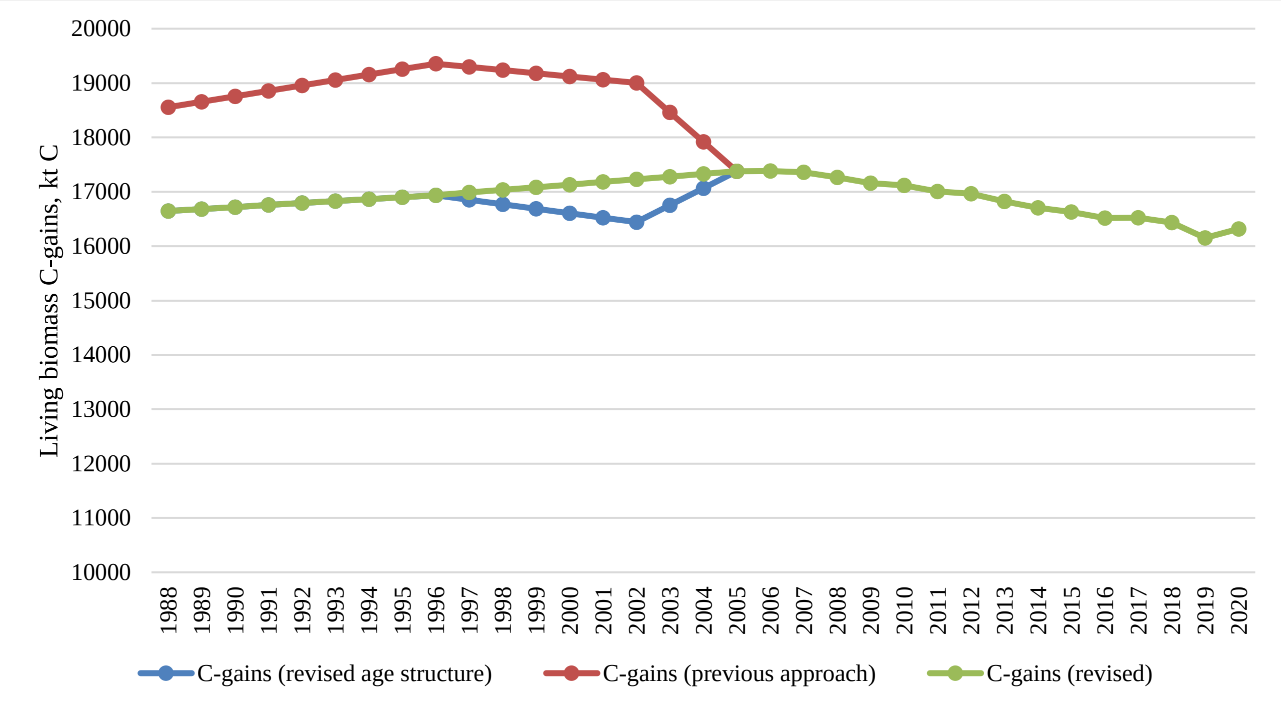


Fig. 6.6. Time series of C-gains before and after revision in 2022 submission

For the calculations it was decided not to take into account the data from 2002. Thus, C-gains for 1990-1995 and 1997-2004 were interpolated based on data for 1988, 1996 and 2005.

Extracted data mentioned above is used for calculation of C-gains, which then is extrapolated to entire area covered by forest vegetation at particular year, as reported in the form 16-zem by the State Service of Ukraine for Geodesy, Cartography and Cadastre.

The data on forests in different regions for 2021 could not be collected since the institution that maintains the forest database (Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt") is located in Irpin that was occupied in early days of the war in Ukraine in 2022. Thus, the level of C-gains remains the same as in 2020 until the data is updated.

Estimation of C-losses from biomass is based on data of the State Statistic Service of Ukraine, which collects information from all of forest enterprises, thus does not need to be extrapolated. More details on methodology are provided in the Annex 3.3.1.

Estimation of CSC in DOM were based on use of Tier 1 methodology. For Forest land remaining Forest land CSC is equal to zero since inputs to DOM is assumed to be equal to outputs. For Land converted to Forest land equation 2.23 of 2006 IPCC, Volume 4, Chapter 2 and EFs from table 2.2 were used.

The ERT by recommendation L.11 asked to revise methodology and EFs used previously for this pool. Ukraine recognizes the need to develop more accurate methodology and EFs (as mentioned in Annex 8.2). For the time until new methodology and EFs will be developed Tier 1 methodology and default EFs will be used.

To estimate CSC in SOM Tier 1 method and default EFs were used (equation 2.25 of 2006 IPCC Guidelines) for Land converted to Forest Land category. Particularly according to Harmonized World Soil Database[5] almost all of the soils are high activity clay soils according to IPCC classification (please see Annex 3.3.1). Thus, SOC_{ref} for moist cold temperate zone with HAC was applied.

Emissions from forest fires are estimated using Tier 1 method and default EFs. 2006 IPCC methodology was adopted for national circumstances for more accurate and complete use of available national statistics. For more detail on the methodology, see the Annex 3.3.1.

During the GHG inventory for 1990-2021, estimation of nitrogen emissions from drainage of Forest Land was performed using Tier 1 method and default EFs [1].

In order to estimate N_2O emissions from the mineralization process when converting land to forest, Tier 1 methodology and default EFs were used.

5 http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

Indirect N_2O emissions from the mineralization process when converting land to forest were estimated. For this purpose, Tier 1 methodology and the default EFs were used.

The summary information regarding methods and emission factors used is presented in Table 6.5.

Table 6.5. Summary information on gases reported, methods and emission factors used for calculations in Forest Land category

CRF category	Gas reported	Method	Emission factor	Note
4.A.1 Forest Land remaining Forest Land - living biomass - DOM, SOM	 CO_2 CO_2	 CS, T2 T1	 CS D	
4.A.2 Land converted to Forest Land - living biomass, DOM, SOM	 CO_2	 CS, T1, T2	 CS, D	
4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils - drained organic soils	CO_2, N_2O	T1	D	
4(III) Direct N2O Emissions from N Mineralization/Immobilization	N_2O	T1	D	
4(IV) Indirect nitrous oxide (N2O) emissions from managed soils	N_2O	T1	D	
4(V) Biomass Burning	CO_2, CH_4, N_2O	CS, T1	D	

6.2.3 Uncertainties and time-series consistency

The primary factors that affect the uncertainty in this category are:

- distribution of forest land areas by categories;
- accuracy of biomass growth estimation;
- accuracy of conversion coefficients.

To estimate uncertainties of GHG emissions and removals approach 1 method (propagation of error) was used (section 3.2.3.1 volume 1 of 2006 IPCC). Uncertainties of data was estimated mostly by expert judgement. Uncertainties of emission factors were taken from 2006 IPCC Guidelines or by expert judgement.

The total uncertainty of emissions/removals for the land-use category Forest Land is 44 %.

Data on input data and uncertainty factors is presented in Table 6.6. Most of uncertainties were derived by expert judgment, as well as taken from 2006 IPCC guidelines for default values.

Table 6.6. Uncertainties in the Forest Land category

Uncertainty of area of forests used in the calculation of C-gains	20 %	Expert judgment
Uncertainty of EFs of C-gains in living biomass	17 %	Expert judgment
Combined uncertainty of C-gains in living biomass	20 %	Calculated
Uncertainty of harvesting data	10 %	Expert judgment
The ratio of above-ground and below-ground biomass	15 %	Expert judgment
Estimation of the amount of carbon in biomass	2 %	IPCC
Combined uncertainty of C-losses of living biomass due to harvesting	21 %	Calculated
Combined uncertainty of C-losses due to disturbances	43 %	Calculated
Uncertainty of land converted into forest land	50 %	Expert judgment

Estimated uncertainty of carbon in the pool of the forest litter of Lands converted to Forest Land	38 %	Expert judgment
Estimated uncertainty of carbon in the pool of the mineral soils of Lands converted to Forest Land	29 %	Expert judgment
Uncertainty of the carbon EF for organic soils	64.7 %	IPCC
Estimated uncertainty of carbon emissions for organic soils	65 %	Calculated
Total uncertainty of carbon stored in biomass on Lands converted to Forest Land	49 %	Calculated
Uncertainty of data on fires	15 %	Expert judgment
Combined uncertainty of emissions from forest fires	17 %	Calculated
Combined uncertainty of emissions in Forest Land category	44 %	Calculated

6.2.4 Category-specific QA/QC procedures

The detailed QA/QC procedures were applied to estimation of GHG emissions and removals.

All the input statistical information is documented and confirmed with official letters from state statistical agencies of Ukraine, archived, and suitable for performing recalculations.

As part of QC procedures, calculations based on national factors were compared with calculations using Tier 1 and default EFs for Forest land remaining forest land. Net biomass CSC resulted in 29 % more C-removals compared to simplified method.

Emissions from fires were also compared with Tier 1 method and default calculations. The comparison resulted in 84 % less emissions than by simplified method. This is mainly caused by use of actual losses of wood compared to the default value.

6.2.5 Category-specific recalculations

The data of forest fires were revised, thus recalculations have been made. Specifically, since 2018 the State Statistic Service of Ukraine has stopped to collect data on wood burned during forest fires. The State Forest Resources Agency of Ukraine provided the answer with no wood burned during forest fires. It was found that the State Forest Resources Agency of Ukraine does not collect the data on burned wood. Thus, the burned wood was recalculated for the years 2018-2021 using the average wood stock and correction factor 0.7 (more details are provided in the annex 3.3.1).

The results of the revisions are presented in the table 6.7.

Table 6.7. The change in GHG emissions in the 4.A Forest land category for the time series from 1990 to 2020

Year	NIR 2021	NIR 2022	Difference, %
2018	-24 182	-24 203	0.1
2019	-25 903	-25 906	0.0
2020	-30 296	-27 131	-10.4

6.2.6 Category-specific planned improvements

Ukraine recognizes the need to develop country-specific factors for Tier 2 method for the category. The research is included into improvement plan, subject to availability of funding.

6.3 Cropland (CRF category 4.B)

6.3.1 Category description

This category includes two subcategories: 4.B.1 Cropland Remaining Cropland and 4.B.2 Land Converted to Cropland. Just as for the category 4.A Forest Land, the 20-year period of land conversion from the subcategory Land Converted to Cropland to the subcategory Cropland Remaining Cropland was applied [1].

The category 4.B Cropland does not include hayfields and pastures, as they are included into the category 4.C Grassland.

Category 4.B is the most significant source of carbon emissions in the LULUCF sector (Fig. 6.1). On the time series GHG total removals in 1990 (-4.6 Mt CO_2-eq.) switched to total emissions in 2021 (48.3 Mt CO_2-eq.). Emissions has increased in comparison with 2020 by 76 %.

The key driver for GHG emissions and removals is N-balance in mineral soil during crop grow (as it is calculated using nationally developed methodology), what is influenced mainly by crop structure (area and volumes harvested) and fertilizers applied (figures 6.2 and 6.3), as well as conversions to Cropland category.

6.3.2 Methodological issues

The key sources of AD are statistical reporting forms on land areas (16-zem), on crop production in Ukraine (harvesting areas, mass and yield) and on fertilizers application. To determine the land converted to the Cropland category, data from the land-use change matrix (Table 6.4) and database were used (for Forest Land converted to Cropland). So far, there is no information on spatial distribution of areas of Cropland (neither for arable lands, orchards and fallow lands). This is expected to be changed after land-use matrices revision due to introduction of GIS data.

The data from 29-sg and 9-bsg forms of national statistics was corrected for 2014-2021 years using the results of analytical study for its use in the national inventory [4].

Carbon in this category is absorbed by the biomass of perennial woody vegetation. Estimations of carbon emissions and removals on such lands were made under Tier 1 using the areas from form 16-zem and the default EFs [1]. There is no data available on areas of harvest of orchards or exact harvest volumes. Thus, to apply Tier 1 method the area of 1990 was divided by default harvest cycle (30 years) to derive areas of different aged orchards. For C-gains all the area was considered, while to calculate C-losses 30-years old perennial woody stands were taken. For more detailed information please see Annex 3.3.2.

To calculate carbon stock dynamics in pool of mineral soils, the methods of nitrogen flow balance were used based on application of the system of national factors. It is relevant for arable lands only. Ukraine does not perform calculations for fallow lands due to lack of reliable input data and methodology consistent with the national methodology of CSC in mineral soils for managed Cropland.

The nitrogen flow method for mineral soils is described in details in the Annex 3.3.2.

Resulting Carbon stock change in SOM pool in 2021 showed significant decrease in emissions. This is the result of several factors, that have the most significant impact on the Nitrogen balance in the soils:

1) harvesting areas and volumes of crops 2 years before the reporting year, as well as in the reporting year;
2) crop types;
3) volumes of organic and nitrogen fertilizers applied into soils.

Each of these factors have a positive or negative effect on Nitrogen increase in the soil (fig. 6.6).

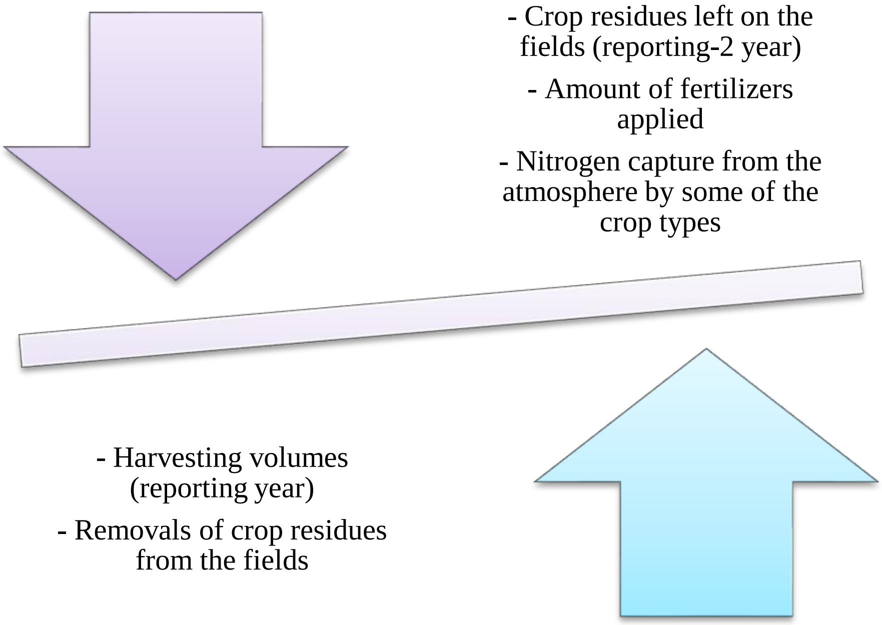


Fig. 6.6. Factors that contribute to increase (above the line) and decrease (below the line) of Nitrogen in SOM pool

In 2021 the combination of the key factors resulted in significant increase of GHG emissions from SOM pool compared with 2020, but the resulting value is similar to the values in 2018 and 2019. Particularly, high volumes of crop residues left in 2018 from high yield of crops, lower yields of crops in 2020 and higher in 2021 (see table 6.8) and significant increase of mineral fertilizers application (see fig. 6.3). Data for the entire time series are provided in the Annex 3.3.2, tables A3.3.15, A3.3.16 and A.3.3.17.

Table 6.8. Harvesting volumes of agricultural crops in Ukraine, thousand tons

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Grain (wheat, rye, barley etc.)	49323	33770	26519	37296	38698	60904	66596	62056	70287	75789	65641	86663
Pulses (beans, peas)	3205	1701	715	757	591	526	905	1277	984	739	632	712
Industrial crops (sugar beet, flax, hemp etc.)	45175	30211	13375	15565	13760	10340	14042	14901	13982	10219	9165	10871
Oilseeds (sun-flower, soy-beans, rape-seeds)	2916	3129	3900	5694	10455	17342	19632	18814	21841	22748	18892	23308
Potato	16602	14689	19833	19464	18707	21348	22269	22739	22989	20748	21326	21847
Vegetables	6238	5879	5833	7300	8076	9728	9934	9778	9950	10204	10152	10442
Melons and gourds	682	494	373	311	751	602	606	457	525	581	518	526
Fodder crops	25277	13242	7264	9087	7479	6992	7375	7259	7290	6985	6646	6383
Grasses for hay and green mass	187544	125549	49520	28787	19515	17552	18180	15683	15929	14945	14147	14875
TOTAL	336973	228665	127334	124261	118048	145354	160996	152969	163783	162962	147124	175639

Calculation of carbon emissions from organic soil pool was held based on data of organic soil areas and the EFs for the temperate zone recommended for use in the 2006 IPCC Guidelines.

In Ukraine, burning of crop residues on agricultural lands is officially forbidden [6], so all fires on cropland are considered as wildfires. Estimation of CH_4, N_2O, CO, and NO_x emissions during burning of plant residues was conducted under Tier 1 of 2006 IPCC Guidelines (equation 2.27) using default factors. To estimate NMVOC emissions, the method and EFs from 2013 EMEP/EEA emission inventory guidebook [8] were used (see Annex 3.3.2).

Information on damaged by fires agricultural land area was received from regional offices of the State Emergency Service of Ukraine and presented in Table 3.3.22, Annex 3.3.2.

In the subcategory of Land converted to Cropland, carbon stock changes were estimated for the pools of living biomass (Forest Land and Grassland converted to Cropland), DOM (Forest Land converted to Cropland) and SOM (for all land-use categories, except Wetlands converted to Cropland, for which no methodological guidance is provided by IPCC, 2006).

CSC from conversions of forests in living biomass is estimated using national factors. Carbon losses from living biomass from conversions of Grassland are estimated using Tier 1 method and default EFs.

To estimate CSC in SOM Tier 1 method and default EFs were used (equation 2.25 of 2006 IPCC Guidelines) for Land converted to Cropland category. Particularly according to Harmonized World Soil Database[6] almost all of the soils are high activity clay soils according to IPCC classification (please see Annex 3.3.1) [7]. Thus, SOC_{ref} for moist cold temperate zone with HAC was applied.

For all converted lands, direct and indirect N_2O emissions from mineralization were estimated using 2006 IPCC equations 11.8 and 11.10, respectively, applying the default EFs.

The summary information regarding methods and emission factors used is presented in Table 6.9.

Table 6.9. Summary information on gases reported, methods and emission factors used for calculations in Cropland category

CRF category	Gas reported	Method	Emission factor	Note
4.B.1 Cropland remaining Cropland - living biomass, DOM - SOM	 CO_2 CO_2	 T1 CS, T3	 D CS	T1 for living biomass is used due to unavailability of data and EFs for application of higher tiers
4.B.2 Land converted to Cropland - living biomass, DOM, SOM	 CO_2	 CS, T1	 CS, D	
4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils - drained organic soils	 CO_2	 T1	 D	
4(III) Direct N2O Emissions from N Mineralization/Immobilization	 N_2O	 T1	 D	
4(IV) Indirect nitrous oxide (N2O) emissions from managed soils	N_2O	T1	D	
4(V) Biomass Burning	CH_4, N_2O	CS, T1	D	

6.3.3 Uncertainties and time-series consistency

The key factors that determine the degree of uncertainty of the GHG emission estimations in the land-use category Cropland are accuracy of:

- amount of crop residues, nitrogen stocks in them, their degree of humification and the level of nitrogen consumption by agricultural crops;
- degree of humification of organic fertilizers, nitrogen amounts in them available to agricultural plants;
- degree of nitrogen consumption by agricultural crops from nitrogen mineral fertilizers;
- amounts of nitrogen input as a result of symbiotic and non-symbiotic fixation;

[6] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

- degree of mineralization of agricultural soils, depending on the type of crop cultivated, the amount of nitrogen stocks in the soils, and their grain texture;
- C:N ratio in the various types of agricultural soils.

The total uncertainty of emissions/sinks for the land-use category Cropland is 92 %.

Data on AD and EFs uncertainty are presented in Table 6.9. Uncertainties for default EFs were taken from 2006 IPCC Guidelines. Uncertainties for CS factors were derived from expert judgments. Calculations of combined uncertainties were performed using approach 1 (propagation of error) from chapter 3 volume 1 of 2006 IPCC.

Table 6.10. Uncertainties in the Cropland category

Uncertainty of EFs of biomass	75 %	IPCC
Combined uncertainty of CSC in living biomass pool in Cropland remaining Cropland	75 %	Calculated
Uncertainty of AD	6 %	Expert judgment
Distribution of harvested crop areas by climatic zones	13.5 %	Scientific research [10]
Nitrogen content in the primary crop products	3.0 %	Scientific research [10]
Nitrogen content in side-production	1.9 %	Scientific research [10]
Nitrogen content in crop residues (above- and below-ground)	18.1 %	Scientific research [10]
Nitrogen consumption by plants from crop residues	18.7 %	Scientific research [10]
Nitrogen inputs into plants from nitrogen mineral fertilizers	8.1 %	Scientific research [10]
Nitrogen inputs into soil from organic fertilizers	14.0 %	Scientific research [10]
Nitrogen inputs into soil from symbiotic fixation	19.4 %	Scientific research [10]
Nitrogen inputs into soil with precipitations	42.9 %	Scientific research [10]
Amount of humus mineralization of soils at crop growing	6.1 %	Scientific research [10]
Consideration of soil type of different mechanical composition areas	38.5 %	Scientific research [10]
Consideration of soil areas of various types of different mechanical composition by climatic zones	47.2 %	Scientific research [10]
Consideration of the C:N ratio for different types of soils	3.1 %	Scientific research [10]
Combined uncertainty of emissions from SOM on Cropland remaining Cropland	93 %	Calculated
Uncertainty of carbon emissions for organic soils	90 %	IPCC
Combined uncertainty of cropland fires	71 %	Calculated
Combined uncertainty of CSC on Lands converted to Cropland	92 %	Calculated
Combined uncertainty of Cropland	84 %	Calculated

Combined uncertainties of resulting GHG emissions and removals highly depend on the total of GHG emissions and removals. This is related to the application of equation 3.2 (chapter 3 volume 1 of 2006 IPCC), since the sign of the value (i.e., emissions or removals) is highly important for the value of denominator, thus on the resulting value of uncertainty.

6.3.4 Category-specific QA/QC procedures

For estimation of GHG emissions in the category Cropland, QA/QC procedures were applied. Correctness of the assumptions made for the estimations was confirmed by expert opinions.

All the input statistical information is documented and confirmed with official letters from state statistical agencies of Ukraine, archived, and suitable for performing recalculations.

Tier 1 method calculation was performed as part of verification of the calculations of CSC in SOM. Particularly equation is 11.6 used to compare national and IPCC approaches of estimation of N in crop residues. The results are presented below in the table 6.11 by groups of crops (calculations were performed by more detailed separation).

There are some national circumstances of above-ground residues use, like for feeding or bedding. Thus, the factor of F_{remove} was adjusted to better reflect the use of by-products from residues of grains and beans and pulses.

The totals estimated by national methodology are bigger by 13 and 34 percent than Tier 1 for above- and below-ground residues respectively, despite there are differences in some particular crop types.

Improvement of factors for Cropland category is in high need, so it is included into improvement plan (annex A8.2).

Table 6.11. Comparison of estimation of N-content in crop residues left on fields

Crops	Tier 1 calculation		National methodology		Difference	
	N above-ground, kg	N below-ground, kg	N above-ground, kg	N below-ground, kg	% above-ground	% below-ground
Grains	324365739	350485246	468579223	555684103	31	37
Beans and pulses	2594480	11390363	66	81	0	0
Industrial crops (incl. sugar beat)	23184029	30880092	1108516	8100946	-1991	-281
Oil crops	258259722	81339951	332668275	259222671	22	69
Vegetables (incl. potato)	49731663	27219107	5094747	7009694	-876	-288
Feeding crops	8241295	4927051	1373760	4558260	-500	-8
Grasses for feeding	75136804	115057042	42939876	68605885	-75	-68
Total Cropland	**736280971**	**598440497**	**844207474**	**907552706**	**13**	**34**
Total Grassland	**5071990**	**14066318**	**10451431**	**7660938**	**51**	**-84**

It should be noticed that estimation of N in crop residues left on agricultural fields in Agriculture and LULUCF sectors are identical. The values calculated then used in Agriculture for calculation of direct N_2O emissions. In LULUCF the remaining part (after subtraction of direct N_2O emissions) is used in further calculations in Cropland and Grassland category (according to the methodology described in annex 3.3).

For N-input from organic fertilizers actual calculations from Agriculture sector was used. Particularly value of available Nitrogen from MMS was used after subtraction of N losses due to direct emissions, which are reported under Agriculture sector. So, with recalculations in Agriculture sector revised values are used then in LULUCF sector. More details with regard to N available from MMS are provided in chapter 5.3.

6.3.5 Category-specific recalculations

Due to recalculations in category 3.B Manure Management, the recalculations in the categories 4.B and 4.C were also synchronized. Particularly, N application to agricultural soils with animal manure was revised for 2017-2020 due to clarification of data described in the Agriculture sector. Nevertheless, it had a minor impact on resulting CSC from mineral soils.

The revisions resulted in changes for 2017-2020.

Table 6.12. The change in GHG emissions in the 4.C Grassland category for the time series from 2017 to 2020

Year	NIR 2022	NIR 2023	Difference, %
2017	39 592	39 592	-0.0000005
2018	47 789	47 789	-0.0000078
2019	50 017	50 017	-0.0000078
2020	27 426	27 426	-0.0000124

6.3.6 Category-specific planned improvements

A work to revise and improve factors used in nitrogen-flow in mineral soils under Cropland was included into improvement plan. This work is also connected with need of verification of Tier 3 methodology, applied by Ukraine, what is a matter of availability of funds.

6.4 Grassland (CRF sector 4.C)

6.4.1 Category description

This category includes two subcategories: 4.C.1 Grassland Remaining Grassland and 4.C.2 Land Converted to Grassland. As well as in the previous categories, the 20-year period of land transition to subcategory 4.C.1 was applied. [1] The subcategory Grassland Remaining Grassland is divided into the managed and unmanaged. Ukraine has revised its approach towards definition of managed and unmanaged grasslands and concluded, that there are no unmanaged grasslands.

This category covers agricultural land systematically used for hay mowing, cattle grazing, the areas from which green mass for cattle feeding with silage material was harvested. Moreover, this category includes hayfields and pastures plowed for the purposes of their radical improvement and permanently used under grass forage crops.

The category Grassland is a net sink of GHG emissions for the years 1990-2018. In 2019-2021 the category became a source with 0.093 Mt CO_2-eq. of emissions, what is lower than in 1990 by 110 % (0.9 Mt CO_2-eq. of removals) and by 50 % than in 2020 (0.062 Mt CO_2-eq.).

GHG emissions and removals in the category is influenced by areas under management for grazing and moving and areas of organic soils, as well as areas of conversions to Grassland category. To a less extent the trend is influenced by fires.

6.4.2 Methodological issues

The data sources for the Grassland category are the statistical forms on land areas (16-zem), on crop production in Ukraine (harvesting areas, mass and yield) and on fertilizers application. The data from this forms for 2014-2021 were corrected with the results of analytical study [4].

Previously assumed as managed grasslands, the areas of grazing or moving is taken from statistic form 29-sg, yearly prepared by the State Statistic Service of Ukraine. Currently this area, as well as grass harvesting, is used in order to calculate CSC in SOM.

Estimation of CSC in biomass and DOM pools were not performed assuming carbon balance in these pools, what is in line with Tier 1 of 2006 IPCC Guidelines. There is insufficiency of data collection, as well as lack of country-specific factors, to apply Tier 2.

To calculate carbon stock dynamics in the pool of mineral soils, the methods of nitrogen flow balance evaluation were used based on application of the national factors. The calculation methods are similar to those used for the pool of mineral soils in the land-use category Cropland (see chapter 6.3.2 and the Annex 3.3.2). The estimation of carbon stock changes in pools of the land-use category Grassland was based on use of data on the areas where grass was directly harvested, the amounts of crop harvested, the yield (based on statistical reporting form 29-sg), as well as data on amounts of organic and nitrogen fertilizers for different crops applied (9-bsg), corrected with use of results of analytical study for 2014-2021 years [4].

The values of the areas that are legally seen within the land-use categories Hayfields and Pastures from statistical reporting form 16-zem exceed the land area from which the crop of hay and green mass was harvested by 60-70 %. Based on the abovementioned, the assumption was made that lands converted to Grassland do not fall under the anthropogenic burden in the category.

To estimate CSC in SOM Tier 1 method and default EFs were used (equation 2.25 of 2006 IPCC Guidelines) for Land converted to Grassland category. Particularly according to Harmonized World Soil Database[7] almost all of the soils are high activity clay soils according to IPCC classification (please see Annex 3.3.1). Thus, SOC_{ref} for moist cold temperate zone with HAC soils was applied.

Calculation of GHG emissions from organic soils Tier 1 method and default EF from 2006 IPCC Guidelines was applied.

The estimation of emissions of non-CO_2 gases includes an inventory from biomass burning processes on pastures, as well as direct and indirect nitrogen emissions from conversion from other land-use categories.

[7] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

Information on fires on grasslands was provided by the specialized institute of the State Emergency Service of Ukraine. The data was provided only starting from 2005, as the statistics were not collected before that year. To derive data for 1990-2004 average value of 2005-2013 years was used. The estimation was held under Tier 1 using the default EFs (Annex 3.3.2).

Calculation of direct and indirect emissions of N_2O due to mineralization was held under Tier 1 using the default EFs for Land converted to Grassland. On Grassland remaining Grassland, the emissions do not take place, as there is an increase in carbon stock in the mineral soil pool.

The summary information regarding methods and emission factors used is presented in Table 6.13.

Table 6.13. Summary information on gases reported, methods and emission factors used for calculations in Grassland category

CRF category	Gas reported	Method	Emission factor	Note
4.C.1 Grassland remaining Grassland -biomass, DOM - SOM	 CO_2 CO_2	 T1 CS, T3	 D CS	 T1 for living biomass is used due to unavailability of data and EFs for application of higher tiers
4.C.2 Land converted to Grassland - living biomass, DOM, SOM	 CO_2	 CS, T1	 CS, D	
4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils - drained organic soils	 CO_2	 T1	 D	
4(III) Direct N2O Emissions from N Mineralization/Immobilization	 N_2O	 T1	 D	
4(IV) Indirect nitrous oxide (N2O) emissions from managed soils	N_2O	T1	D	
4(V) Biomass Burning	CO_2, CH_4, N_2O	T1	D	

6.4.3 Uncertainties and time-series consistency

The key factors that influence the degree of uncertainty of the GHG emission estimations in the land-use category 4.C Grassland are the following:

- amount of crop residues, nitrogen stocks in them, their degree of humification and the level of consumption of the nitrogen by agricultural crops;
- degree of humification of organic fertilizers, nitrogen amounts in them available to agricultural plants;
- the level of consumption of nitrogen fertilizers by agricultural crops;
- degree of mineralization of agricultural soils, depending on the type of crop cultivated, the amount of nitrogen stocks in the soils, and their grain texture;
- C:N ratio in the various types of agricultural soils.

The total uncertainty of emissions/removals for the land-use category 4.C Grassland is 330 %.

Data on input data and uncertainty factors are presented in Table 6.14. Uncertainties for default EFs were taken from 2006 IPCC Guidelines. Uncertainties for CS factors were derived from expert judgments. Uncertainties for CS factors were derived from expert judgments. Calculations of combined uncertainties were performed using approach 1 (propagation of error) from chapter 3 volume 1 of 2006 IPCC.

Table 6.14. Uncertainties in the Grassland category

Uncertainty of AD	6 %	Expert judgment
Distribution of harvested crop areas by climatic zones	13.5 %	Scientific research [10]
Nitrogen content in the primary crop products	3.0 %	Scientific research [10]

Nitrogen content in side-production	1.9 %	Scientific research [10]
Nitrogen content in crop residues (above- and below-ground)	18.1 %	Scientific research [10]
Nitrogen consumption by plants from crop residues	18.7 %	Scientific research [10]
Nitrogen inputs into plants from nitrogen mineral fertilizers	8.1 %	Scientific research [10]
Nitrogen inputs into soil from organic fertilizers	14.0 %	Scientific research [10]
Nitrogen inputs into soil from symbiotic fixation	19.4 %	Scientific research [10]
Nitrogen inputs into soil with precipitations	42.9 %	Scientific research [10]
Amount of humus mineralization of soils at crop growing	6.1 %	Scientific research [10]
Consideration of soil type of different mechanical composition areas	38.5 %	Scientific research [10]
Consideration of soil areas of various types of different mechanical composition by climatic zones	47.2 %	Scientific research [10]
Consideration of the C:N ratio for different types of soils	3.1 %	Scientific research [10]
Combined uncertainty of emissions from SOM on Grassland remaining Grassland	45 %	Calculated
Uncertainty of carbon emissions for organic soils	90 %	IPCC
Combined uncertainty of grasslands fires	71 %	Calculated
Combined uncertainty of CSC in living biomass pool on Lands converted to Cropland	76 %	Calculated
Combined uncertainty of CSC in SOM pool on Lands converted to Cropland	92 5	Calculated
Combined uncertainty of Grassland	330 %	Calculated

Combined uncertainties of resulting GHG emissions and removals highly depend on the total of GHG emissions and removals. This is related to the application of equation 3.2 (chapter 3 volume 1 of 2006 IPCC), since the sign of the value (i.e., emissions or removals) is highly important for the value of denominator, thus on the resulting value of uncertainty.

6.4.4 Category-specific QA/QC procedures

For estimation of GHG emissions in the category 4.C Grassland, QA/QC procedures were applied. Correctness of the assumptions made for the estimations was confirmed by specialized experts' opinions.

All the input statistical information is documented and confirmed with official letters from state statistical agencies of Ukraine, archived, and suitable for performing recalculations.

As described in chapter 6.3.4, as a part of verification, estimation of N volumes in residues left to decay on fields using Tier 1 was performed. The result of analysis shows that the national methodology results in less N from below-ground residues by 84 %, but more N from above-ground residues by 51 %.

Improvement of factors for national methodology is in high need, so it is included into improvement plan (Annex 8.2).

6.4.5 Category-specific recalculations

As described in the chapter 6.3.5 there were recalculation of CSC in mineral soils due to revision of N application to soils with animal manure. That, in turn, is connected to recalculations in category 3.B Manure Management. Nevertheless, it had a very minor impact on resulting CSC from mineral soils.

Table 6.15. The change in GHG emissions in the 4.C Grassland category for the time series from 2017 to 2020

Year	NIR 2021	NIR 2022	Difference, %
2016	-451	-451	0.00000002
2017	-244	-244	0.00000052
2018	21	21	-0.00000897
2019	65	62	-3.84787180

6.4.6 Category-specific planned improvements

Because the approach of CSC determination in mineral soils on Grassland is identical as on Cropland, general work to revise and improve factors used in nitrogen-flow in mineral soils was included into improvement plan. This work is also connected with need of verification of Tier 3 methodology, applied by Ukraine, what is a matter of availability of funds.

Planned work of revision of land-use matrix is expected to deliver more accurate results regarding land areas converted to Grassland.

6.5 Wetlands (CRF sector 4.D)

6.5.1 Category description

According to requirements of the 2006 IPCC Guidelines [1], this land-use category includes territories of marshes and land under inland water objects. In Ukraine, the land-use category 4.D Wetlands includes land not occupied by forests that is partly, temporarily or permanently flooded with water.

This category includes subcategories 4.D.1 Wetlands Remaining Wetlands and 4.D.2 Land Converted to Wetlands with the transition period of 20 years.

The 2006 IPCC Guidelines also subdivide wetlands into the three types:

- Peat extraction;
- Flooded land;
- Other wetlands.

In the Peat Extraction category, operating peat extraction sites are reported. Other areas of wetlands are reported as Other Wetlands due to lack of statistics that would allow separating flooded lands, according to the IPCC terminology.

6.5.2 Methodological issues

The area of subcategory 4.D.1 Wetlands remaining Wetlands was taken from reporting form 16-zem. The category Peat extraction remaining Peat extraction includes the areas where peat extraction takes place (form 16-zem). The rest of the territory, for the exception of peatlands and that converted into wetlands, was classified as Other Wetlands. Flooded lands are not reported due to lack of national statistics on this land-use type that would be consistent with the 2006 IPCC Guidelines.

The estimation of emissions was held under Tier 1 using the default EFs for subcategory 4.D.1. In order to consider recommendation of ERT 2013 Wetlands Supplement was used for the calculations in this category [13].

Data on peat extraction volumes were obtained from the State Statistics Service of Ukraine (Table 6.16). Data on imports and exports of non-energy peat in Ukraine is not available. The conservative assumption was made, according to which imports equals exports, so the amount of peat used is equal to the amount produced.

Areas of subcategory 4.D.2 were extracted from the land-use change matrix, as well as from the database of activity under Article 3.3 KP (Forest Land converted to Wetlands).

Estimation of the carbon stock change in the land-use category 4.D.2 Land Converted to Peat Extraction was not performed, because there are no statistics on the areas converted to this subcategory. According to data of the State Service of Geodesy, Cartography and Cadastre of Ukraine, the areas of peat extraction have been constantly decreasing throughout the entire time series from 32.1 kha in 1990 to 11.7 kha in 2000, and to 8.9 kha in 2021. At the same time, there is a gradual increase in the total area of the land-use category 4.D Wetlands, according to statistical reporting form 16-zem. It was therefore decided that conversions occur either to Flooded Land or Other Wetlands.

Currently there is no information on what soils conversions occur. Considering that the areas of organic soils in Forest land, Cropland and Grassland is rather stable, assumption was made that these conversions to Wetlands occur on mineral soils. Nevertheless, this might be confirmed as soon as GIS data on land representation be used.

2006 IPCC Guidelines provide a method under Tier 1 for estimation of biomass losses only during conversions to Flooded Lands. Ukraine applied it for the subcategory 4.D.2, and also conservative approach was used that all carbon stock in DOM pool is oxidized during conversions of forests.

Table 6.16. Production of non-agglomerated peat for use in agriculture for non-energy purposes, kt of conditional humidity

Year	Production
1990	14680
1991	11678
1992	5738
1993	2160
1994	799
1995	481
1996	250
1997	66
1998	99
1999	115
2000	88
2001	108
2002	152
2003	164
2004	163
2005	119
2006	159
2007	217
2008	243
2009	242
2010	170
2011	221
2012	210
2013	131
2014	119
2015	79
2016	136
2017	88
2018	146
2019	140
2020	121
2021	163

Amount of N_2O emissions from peat extraction was estimated using default EFs.

On-site and off-site CO_2 emissions were estimated by equation 2.2 from Wetlands Supplement. CH_4 emissions from ditches were estimated using equation 2.6. N_2O emissions were estimated using equation 2.7. EFs for the calculations were taken from Wetlands Supplement.

On the conversions of lands to Wetlands it was assumed that entire C-stocks are lost from living biomass (Forest land and Grassland) and from DOM (Forest land).

GHG emissions from mineralization of nitrogen at conversion (direct and indirect) were estimated under Tier 1 using default coefficients (equation 11.8 of 2006 IPCC Guidelines).

In the current NIR, emissions from peat bogs burning have been estimated. Information on burning of biomass on non-forest organic soils was provided by the Ukrainian Scientific Research Institute of Civil Protection. As well as in the case of fires on Grasslands, the data are only available starting from 2005, and for 1990-2004 it was derived as average value for available data for 2005-2013 years (Table 3.3.23 of Annex 3.3.2).

Tier 1 method of 2006 IPCC Guidelines was used for calculation of GHG emissions from fires. To obtain emission factors, the 2013 Supplement to the 2006 IPCC Guidelines was used (IPCC, 2013). The volumes of the organic matter available for combustion was taken as 100 tons of dry matter in the way as applied for underground forest fires according to national studies [10], and the values from Table 2.7 of 2013 IPCC Supplement were applied for GHG emissions estimations [11].

The summary information regarding methods and emission factors used is presented in Table 6.17.

Table 6.17. Summary information on gases reported, methods and emission factors used for calculations in Wetlands category

CRF category	Gas reported	Method	Emission factor	Note
4.D.1 Wetlands remaining Wetlands - Peat extraction remaining Peat extraction	CO_2	T1	D	
4.D.2 Land converted to Wetlands - living biomass, DOM, SOM	CO_2	T1	CS, D	
4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils - Peat extraction - drained organic soils	CO_2, CH_4, N_2O	T1	D	
4(III) Direct N2O Emissions from N Mineralization/Immobilization	N_2O	T1	D	
4(IV) Indirect nitrous oxide (N2O) emissions from managed soils	N_2O	T1	D	
4(V) Biomass Burning	CO_2, CH_4, N_2O	T1	CS, D	

6.5.3 Uncertainties and time-series consistency

The key uncertainty factor in estimation of GHG emissions in the land-use category 4.D Wetlands is accuracy of determining the areas that are part of this land-use category and permanently remain within this category.

Areas of land-use categories are defined according to data of the State Service of Geodesy, Cartography and Cadastre of Ukraine. For territories within the land-use category, the area accuracy is taken to be 10 %. Data on production of non-energy peat was obtained from the State Statistics Service, the uncertainty of which is taken as 5 %.

To estimate emissions from peat extraction, default factors were used as well as its uncertainties. Current inventory also includes emissions from fires on non-forest peat lands. Thus, uncertainty of CO_2 emissions is 32 %. The uncertainty of methane emissions from fires is 29 %. The uncertainty of nitrogen emissions from peat lands is 38 %.

The total uncertainty in the 4.D Wetlands category is 32 %.

6.5.4 Category-specific QA/QC procedures

For estimation of GHG emissions in the category 4.D Wetlands QA/QC procedures were applied. All the input statistical information was documented, archived, and accessible for recalculations.

6.5.5 Category-specific recalculations

There were no recalculations in the category.

6.5.6 Category-specific planned improvements

Planned work of revision of land-use matrix is expected to deliver more accurate results regarding land areas of Wetlands.

6.6 Settlements (CRF sector 4.E)

6.6.1 Category description

All land occupied by industrial facilities, residential houses, roads, mines, open development sites, and any other facilities established for various types of human activities, including the areas for their maintenance are included in the land-use category 4.E Settlements.

6.6.2 Methodological issues

This category is divided into subcategories 4.E.1 Settlements Remaining Settlements and 4.E.2 Land Converted to Settlements.

Estimation of carbon stock changes in the land-use category 4.E.1 Settlements remaining Settlements was not performed due to that there are no national values of carbon stock changes in green vegetation on built-up land. Use of the factors suggested in 2006 IPCC Guidelines [1] may lead to significantly inflated results of removals estimation, as they were designed for tree species typical of North America, while in Ukraine the tree species structure in this land-use category is different.

Estimation of CO_2 emissions for the subcategory Forest Land Converted to Settlements is produced in pools of living biomass and dead organic matter in case there are deforestation activities on a basis of instant oxidation.

To estimate CSC in SOM Tier 1 method and default EFs were used (equation 2.25 of 2006 IPCC Guidelines) for Land converted to Settlements category. Particularly according to Harmonized World Soil Database[8] almost all of the soils are high activity clay soils according to IPCC classification (please see Annex 3.3.1). Thus, SOC_{ref} for moist cold temperate zone with HAC soils was applied.

Nitrogen direct and indirect emissions from mineralization at conversion were estimated under Tier 1 using the default EFs (equation 11.8 of the 2006 IPCC Guidelines).

The summary information regarding methods and emission factors used is presented in Table 6.18.

Table 6.18. Summary information on gases reported, methods and emission factors used for calculations in Settlements category

CRF category	Gas reported	Method	Emission factor	Note
4.E.2 Land converted to Settlements - living biomass, DOM, SOM	CO_2	T1	CS, D	
4(III) Direct N2O Emissions from N Mineralization/Immobilization	N_2O	T1	D	
4(IV) Indirect nitrous oxide (N2O) emissions from managed soils	N_2O	T1	D	

6.6.3 Uncertainties and time-series consistency

Uncertainty level of the category is defined mostly by conversions to Settlements. In 2021 conversion of Forest land to Settlements occurred. Because of Tier 1 method of CSC calculations for

[8] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

these land-use conversions, total uncertainty level of GHG emissions in the category 4.E Settlements is 64 %.

6.6.4 Category-specific QA/QC procedures

For estimation of GHG emissions in the 4.E Settlements category, general QA/QC procedures were applied. All the input statistical information was documented, archived, and accessible for recalculations.

6.6.5 Category-specific recalculations

There were no recalculations in this category.

6.6.6 Category-specific planned improvements

Planned work of revision of land-use matrix is expected to deliver more accurate results regarding land areas of Settlements.

6.7 Other Land (CRF sector 4.F)

6.7.1 Category description

The category 4.F Other Land includes open land without vegetation or with little vegetation [2] - open land, the surface of which is not or almost not covered with vegetation, namely: rocky sites (land under bare rocks, landslides, pebbles, gravel, sand, including beaches), ravines (linear erosional land form) with the depth of more than 1 m with no or poorly formed soil cover and emersions of rock or lower genetic soil layers on the slopes, other open land (saline etc.).

6.7.2 Methodological issues

For the land-use category 4.F Other Land remaining Other Land the assumption about absence of carbon stock changes was made.

According to the 2006 IPCC Guidelines [1], this land use category is seen as a balancing one to provide a stable final value of the areas in Ukraine along the time series - 60,354.9 thousand km^2, and includes areas with very low carbon stocks.

Carbon stock changes from conversions of forests, cropland and grassland into other land were estimated. The estimation was made under Tier 1 method, equation 2.25 [1], using the default EFs (Table 2.3, 5.5 and 6.2 [1]). It should be noted that according to 2006 IPCC Guidelines [1], the carbon stock after conversion is equated to zero.

For converted land, direct and indirect N_2O emissions from mineralization of nitrogen at conversion were also estimated. The estimation was made under Tier 1 method using the default EFs (equation 11.8 of 2006 IPCC Guidelines). For the time series, these emissions were estimated and included into the relevant CRF tables.

The summary information regarding methods and emission factors used is presented in Table 6.19.

Table 6.19. Summary information on gases reported, methods and emission factors used for calculations in Other Land category

CRF category	Gas reported	Method	Emission factor	Note
4.F.2 Land converted to Other Land				

CRF category	Gas reported	Method	Emission factor	Note
- living biomass, DOM, SOM	CO_2	T1	CS, D	
4(III) Direct N2O Emissions from N Mineralization/Immobilization	N_2O	T1	D	
4(IV) Indirect nitrous oxide (N2O) emissions from managed soils	N_2O	T1	D	

6.7.3 Uncertainties and time-series consistency

In 2021 there was conversion of Forest land to Other land. Uncertainty of GHG emissions of which was estimated as 14 %.

GHG emissions from cropland and grassland conversions to other land were estimated, using Tier 1 method and default EFs with 92 % and 91 % of uncertainties correspondingly. Due to that total uncertainty of 4.F Other Land category is 130 %.

6.7.4 Category-specific QA/QC procedures

For estimation of GHG emissions in the 4.F Other Land category, general QA/QC procedures were applied. All the input statistical information was documented, archived, and accessible for recalculations.

6.7.5 Category-specific recalculations

There were no recalculations in the category.

6.7.6 Category-specific planned improvements

Planned work of revision of land-use matrix is expected to deliver more accurate results regarding land areas of Other land.

6.8 Harvested Wood Products (HWP, CRF sector 4.G)

6.8.1 Category description

HWP category includes estimations of C-stocks by 3 types of HWP: sawnwood, wood-based panels and paper and paperboard. The dynamics of Carbon stock changes in Sawnwood and Wood-based Panels have similar trends, since the majority of wood harvested in Ukraine is used domestically (fig. 6.7). This tendency became even stronger due to prohibition to export industrial roundwood since 2015. Consequently, the production of sawnwood increased in recent reported years.

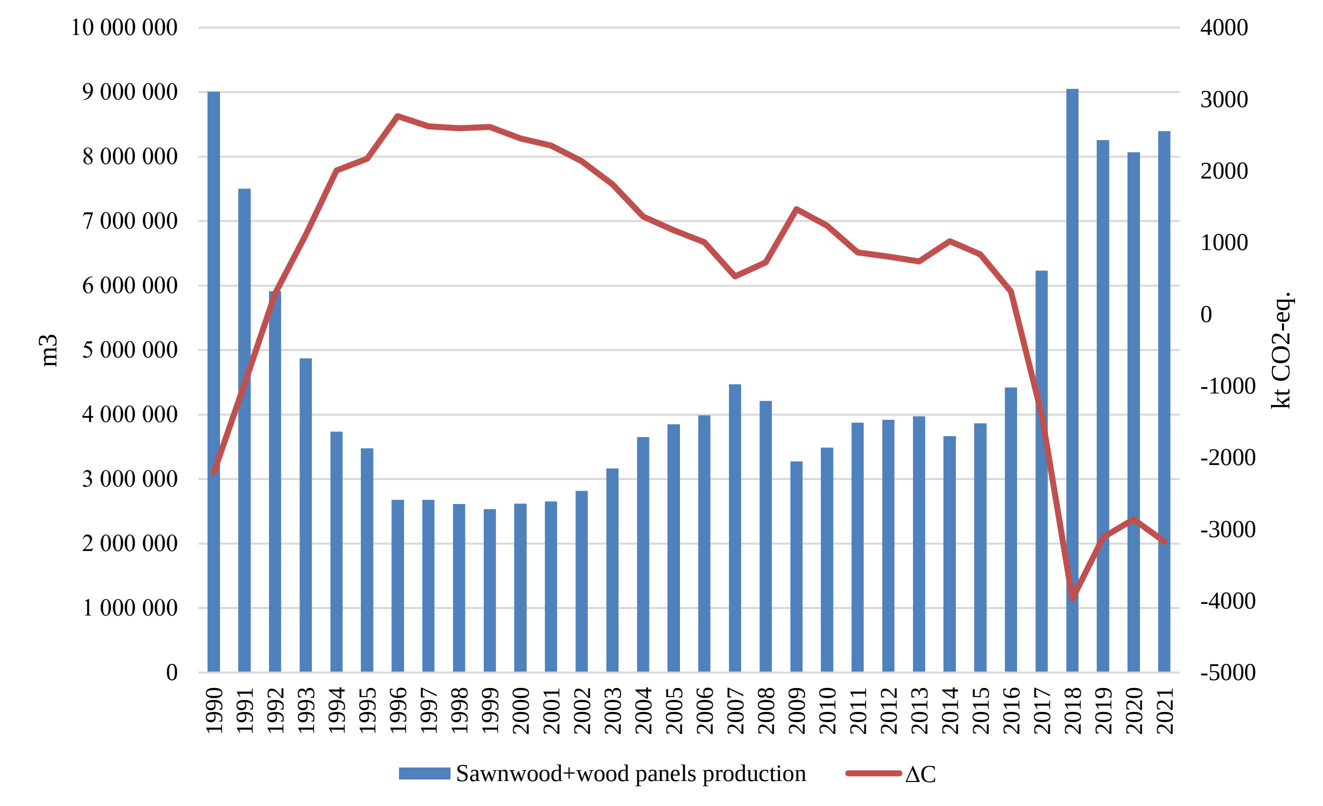


Fig. 6.7. Production and Carbon stock changes in the Sawnwood and Wood-based Panels subcategories combined

Paper and paperboard subcategory has a different tendency, since the production of these commodities are based on imported pulp. Consequently, despite the production volumes of paper and paperboard since 2012 varies between 1.0-1.2 million t, Carbon stocks in the subcategory is going towards zero due to the lack of domestic pulp production since 2012.

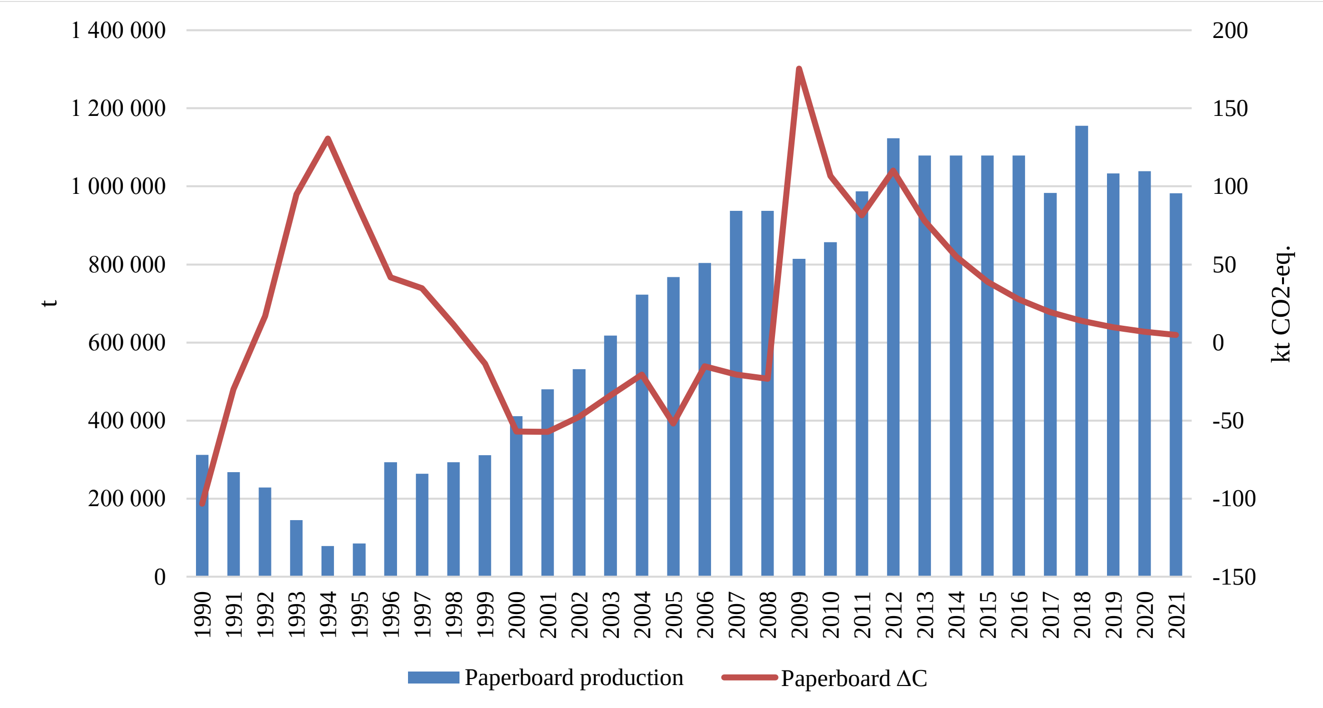


Fig. 6.8. Production and Carbon stock changes in the Paper and Paperboard subcategory

There are significant changes in timber and wood products flows to and from Ukraine particularly due to prohibition to export industrial roundwood, which had historically significant amounts. Consequently, the production of sawnwood increased in recent reported years.

6.8.2 Methodological issues

Estimation of carbon stock in the HWP category was made under Tier 1 method using the default EFs. The production approach to estimation of carbon stock changes in the category was applied.

The input information (table 6.20) includes FAO databases and national data provided by the State Statistics Service of Ukraine and the State Forest Resources Agency of Ukraine.

Table 6.20. Activity data for calculations in HWP category

	Sawnwood Production, m3	Wood Panels Production, m3	Paper and Paperboard Production, t
1990	7 441 000	1 564 365	312 325
1991	6 106 000	1 395 154	267 888
1992	4 700 000	1 215 000	228 790
1993	3 882 000	988 000	145 290
1994	3 124 000	614 000	78 500
1995	2 917 000	560 000	85 200
1996	2 296 000	382 000	292 890
1997	2 306 000	372 000	264 000
1998	2 258 000	355 000	292 900
1999	2 141 000	392 000	310 900
2000	2 127 000	490 000	411 000
2001	1 995 000	659 000	479 900
2002	1 950 000	868 300	531 600
2003	2 197 000	970 000	618 037
2004	2 414 000	1 239 000	722 999
2005	2 409 000	1 443 000	768 010
2006	2 385 000	1 604 000	804 000
2007	2 525 000	1 944 000	937 001
2008	2 266 000	1 944 000	937 001
2009	1 753 000	1 522 000	813 999
2010	1 736 000	1 751 000	857 001
2011	1 888 000	1 989 000	986 998
2012	1 823 000	2 097 300	1 123 060
2013	1 804 000	2 167 700	1 079 350
2014	1 780 900	1 886 000	1 079 350
2015	1 928 954	1 936 000	1 079 350
2016	2 150 842	2 267 700	1 079 350
2017	2 498 003	3 736 700	983 000
2018	3 270 975	5 780 700	1 155 000
2019	3 095 911	5 163 700	1 033 000
2020	3 018 601	5 050 700	1 039 000
2021	2 212 248	6 183 700	982 429

Production of sawnwood is provided by the State Statistic Service of Ukraine. The data regarding production of wood-based panels and paper and paperboard was taken from FAO database. FAO has no information for 1990-1991 years for production of wood-based panels and paper and paperboard, thus splicing technique was applied using GDP of Ukraine, derived from the data of World Bank (see fig. 6.9 and 6.10).

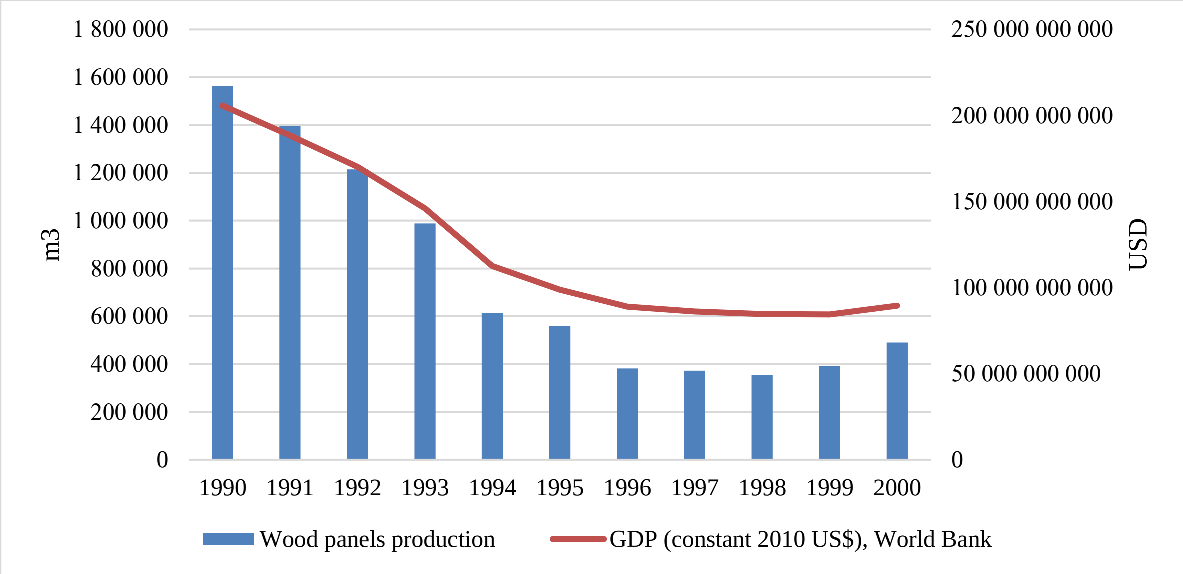


Fig. 6.9. Estimation of wood panels production based on GDP

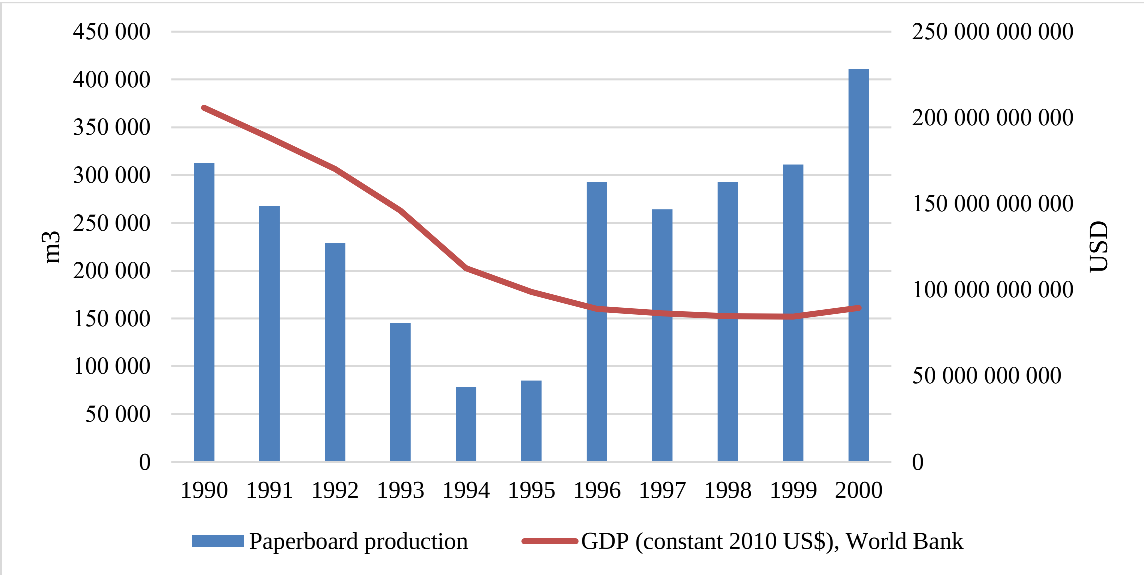


Fig. 6.10. Estimation of paperboard production based on GDP

GHG inventory in 4.G category was performed with stratification on Sawnwood, Wood-Based Panels and Paper and Paperboard with corresponding AD and EFs [13].

The method and calculation factors (table 6.21) were taken from the KP-Supplement to 2006 IPCC Guidelines.

Table 6.21. Factors used for calculations in HWP category

	Sawnwood	Wood-Based Panels	Paper and Paperboard
Half-life, years	35	25	2
C Conversion factor, Mg C/ m^3 or Mg C/ Mg	0.229	0.269	0.386
Density, Mg(dry oven mass)/ Mg	-	-	0.9

To estimate the final HWP contribution into emissions/removals in the sector, the production approach was applied.

6.8.3 Uncertainties and time-series consistency

The data for HWP calculations was derived from the State Statistic Service of Ukraine, for which 10 % of uncertainty was applied. For FAO data 15 % was applied as for countries with systematic control.

Factors for calculations are considered to have high uncertainty, what is recognized by IPCC. KP Supplement do not provide particular uncertainty values, thus values from 2006 IPCC were used (table 12.6 of Chapter 11 Volume 4): factor of product volume to weight factor – 25 %, oven dry weight to carbon factor – 10 %, decay rate – 50 %.

With use of propagation of errors method combined uncertainty of sawnwood is estimated to be 41 %, wood panels is 40 % and paper and paperboard is 48 %.

6.8.4 Category-specific QA/QC procedures

For estimation of GHG emissions in the 4.G Harvested Wood Products category, general QA/QC procedures were applied. All the input statistical information was documented, archived, and accessible for recalculations.

6.8.5 Category-specific recalculations

There were recalculations in the category due to data clarification by FAO. Particularly, the data on production of wood-based panels were clarified for 2017-2020 and production of paper and paperboard in 2020.

The results of this revision are provided in the table 6.22.

Table 6.22. The change in GHG emissions in the 4.G HWP category for the time series from 1990 to 2019

Year	NIR 2022	NIR 2023	Difference, %
2017	119	-1 377	-1256.6
2018	-1 515	-3 956	161.1
2019	-1 119	-3 102	177.3
2020	-1 045	-2 856	173.2

6.8.6 Category-specific planned improvements

There are no improvements planned in this category.

7 WASTE (CRF SECTOR 5)

7.1 Sector Overview

In the "Waste" sector, GHG emissions in the following categories are accounted for:

- 5.A Solid Waste Disposal;
- 5.B Biological Treatment of Solid Waste;
- 5.C Incineration and Open Burning of Waste;
- 5.D Wastewater Treatment and Discharge.

Methane emissions in the sector come from decomposition of the organic matter in solid municipal and industrial waste landfills, from treatment of industrial and domestic water, waste incineration and composting. Nitrous oxide emissions are caused by treatment of industrial wastewater, human life wastewater, incineration and composting of waste. Carbon dioxide is accounted for at waste incineration.

Based on findings of the inventory, greenhouse gas emissions in the sector in 2021 amounted to 12 160.18 kt of CO_2-eq.; including methane – 11 076.65 kt of CO_2-eq. (443.07 kt); nitrous oxide – 1 078.17 kt of CO_2-eq. (3.62 kt); and carbon dioxide – 5.36 kt. The decrease in compared to the baseline 1990 (12 446.53 kt of CO_2-eq.) is 2.3 %. The decrease in compared to the previous year is 1.66 %. For details on the sector emission trends and emission values, see Tables 7.1, 7.2 and Fig. 7.1.

Table 7.1 GHG emissions in "Waste" sector according to the gases and categories in particular years

Year	CO_2	CH_4	N_2O	5.A	5.B	5.C	5.D	Total GHG
	kt CO_2-eq							
1990	28.68	10696.76	1721.10	6534.85	34.36	34.69	5842.64	12425.39
1995	26.66	10631.01	1312.69	7278.76	23.23	30.60	4637.77	11956.15
2000	34.54	10589.38	1168.97	7376.58	9.71	38.98	4367.63	11781.49
2005	49.50	11141.60	1239.96	7639.24	5.10	55.92	4730.81	12416.15
2010	52.91	11456.08	1223.05	8035.20	3.03	59.24	4634.56	12732.04
2011	45.08	11496.88	1227.55	8060.61	5.49	52.97	4650.44	12769.51
2012	34.69	11373.60	1237.13	8003.23	6.41	38.52	4597.26	12645.41
2013	3.31	11600.57	1246.51	8082.15	7.33	4.54	4756.37	12850.39
2014	11.04	11434.30	1196.36	8094.76	12.98	13.73	4520.24	12641.70
2015	8.35	11424.05	1131.99	8229.60	39.48	10.16	4285.16	12564.39
2016	5.38	11612.65	1132.48	8232.27	34.98	8.45	4474.82	12750.52
2017	5.93	11544.07	1117.08	8115.38	25.80	8.79	4517.11	12667.08
2018	5.30	11489.30	1118.63	7972.55	28.52	8.83	4603.34	12613.23
2019	3.55	11472.74	1104.68	7878.93	8.40	7.80	4685.85	12580.97
2020	3.88	11264.32	1097.42	7703.22	7.49	8.94	4645.97	12365.62
2021	5.36	11076.65	1078.17	7699.52	17.29	12.39	4430.97	12160.18

Table 7.2 Methods and emission factors used in estimations of emissions from "Waste" sector

Sector categories	Reported GHG	Methods	EF
A Solid Waste Disposal			
1. Managed waste disposal sites	CH_4	Tier 3	CS, D
2. Unmanaged waste disposal sites	CH_4	Tier 3	CS, D
3. Uncategorized waste disposal sites	NO	NA	NA
B. Biological treatment of solid waste			
1. Composting	CH_4, N_2O	Tier 1	D
2. Anaerobic digestion at biogas facilities	NO	NA	NA
C. Incineration and open burning of waste			
1. Waste incineration	CO_2, N_2O, CH_4	Tier 1, Tier 2	CS, D
2. Open burning of waste	NE	NA	NA
D Wastewater Treatment and Discharge			
1. Domestic wastewater	CH_4, N_2O	Tier 1, Tier 2	CS, D
2. Industrial wastewater	CH_4, N_2O	Tier 2	CS, D

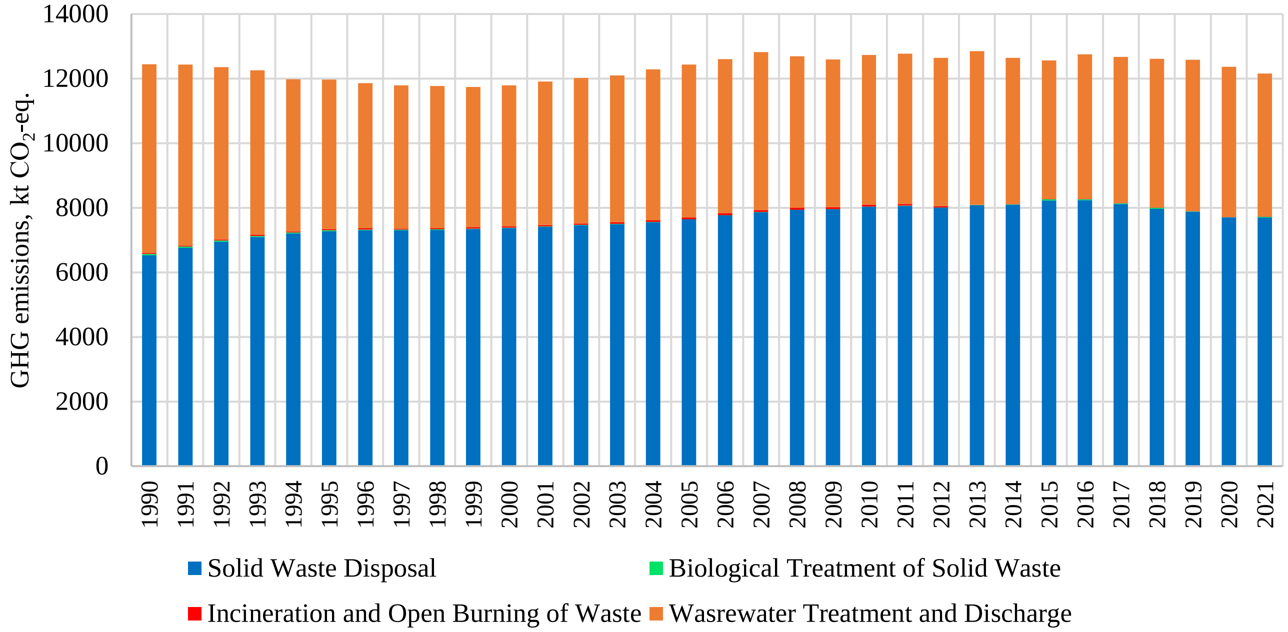


Fig. 7.1. GHG emissions in the "Waste" sector, 1990-2021

Since 1990, emissions from waste management gradually decreased and reached their minimum value in 1999, this period was characterized by a sharp drop in industrial production and, as a result, reduced emissions from treatment of industrial wastewater. In the period of 1999-2007, emissions increased significantly – by 9.2 % – due to increased volumes of municipal solid waste (MSW) landfilling, as well as an increase in the volume of industrial wastewater. In 2008, there was a slight reduction in GHG emissions associated with the global economic crisis. In 2014, GHG emissions in the "Waste" sector started to decrease constantly mainly due to the reduction of water consumption for industrial and household needs and an increase of methane utilization at MSW landfills.

7.2 Solid Waste Disposal (CRF category 5.A)

7.2.1 Category description

Inventory of GHG emissions from solid waste landfills in Ukraine includes methane emissions from MSW landfilling, as well as industrial organic waste in dumping sites and MSW landfills of the country, which could be divided into the three groups in accordance to the classification of 2006 IPCC Guidelines [1]: unmanaged shallow, unmanaged deep, and managed (controlled). Category 5.A is a key one and estimated under Tier 3 using the national emission factors and the default factors according to [1].

Methane emissions from solid waste landfills in 1990 amounted to 261.39 kt, and by 2021 they have increased to 307.98 kt – by 17.8 %. In comparison with the previous year emissions were decreased by 0.05 %.

In the period of 1990-1996, there was a significant increase in emissions – by 11.86 %, which was due to modernization of operated MSW dumping sites up to the level of managed ones according to [1]. In 1997-2004, emissions remained at the level of 292.26-302.29 kt. This period is characterized by an increase in volumes of solid waste landfilled and continued modernization of MSW dumping sites, however the slight increase in methane emissions during the period was due to a sharp decrease in biodegradable carbon content in MSW due to reduction of the paper fraction share. By 2010, emissions increased slightly as a result of further increase in the scope of MSW landfilling. In 2011-2021, methane emission fluctuations mainly were caused by landfill gas utilization.

Methane emissions from solid waste disposal for 1990-2021 are shown at figure 7.2.

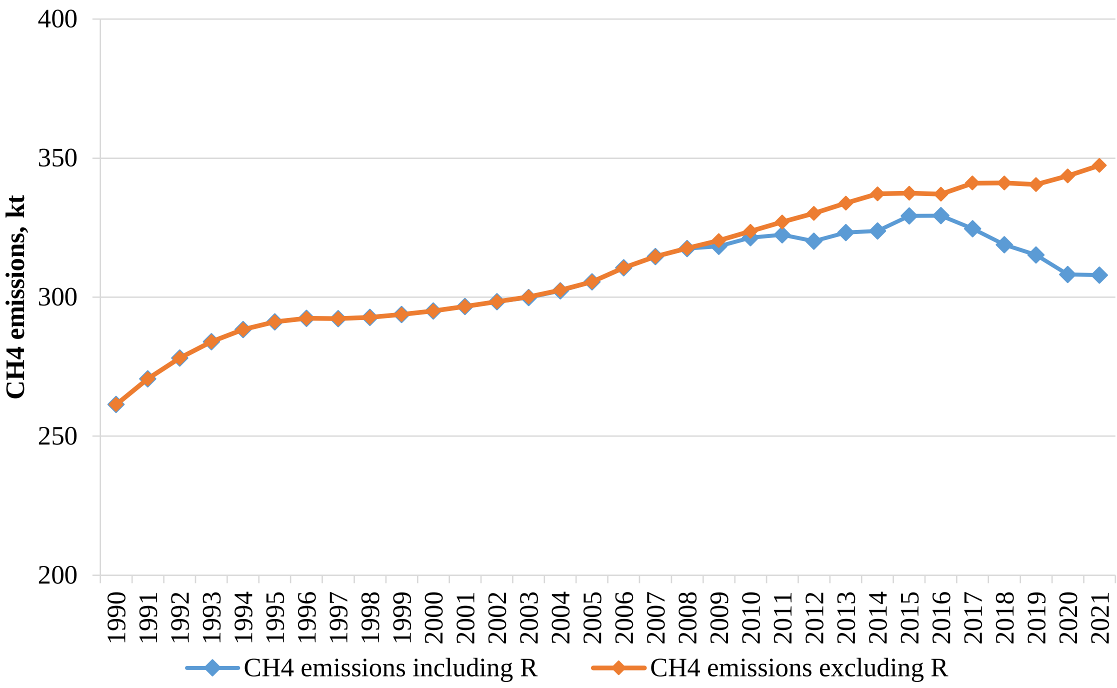


Fig. 7.2. Methane emissions from solid waste disposal, 1990-2021

7.2.2 Methodological issues

7.2.2.1 General principles

Estimation of CH_4 emissions from MSW landfills was performed in accordance with the National Multicomponent Model developed in 2012 and described in the scientific research work "Study on gasification at the largest MSW dumping sites and switching to the three-component national model for estimation of GHG emissions from MSW dumping sites in Ukraine" [2]. In paper [3], the model was improved by means of more detailed assessment of MSW composition and separation of two additional components (leather and rubber, as well as personal care products).

The National Gasification Model is based on the first-order decay method of the third level of detail (formulas 3.A1.1-3.A1.6 [1]), which is based on Ukraine-specific factors determined for each of the seven organic fraction of municipal solid waste [2, 3].

In accordance with the model, annual emissions of methane at landfilling of MSW delivered in the current year and in previous years are determined by the formula:

$$Q(t) = \sum_{j=1}^{m} \sum_{i=1}^{n} A \cdot k_j \cdot MWS_i \cdot MWS_{j,i} \cdot L_{0\ j,i} \cdot e^{-k_j \cdot (t-x)} , \qquad (7.1)$$

where: $Q\ (t)$ – the amount of methane produced in the period t, t;

k_j – the constant of the rate of methane production for the j-th component, year^{-1};

A – the normalizing factor correcting the sum, determined by the formula:

$$QA = (1 - e^{-k_j})/k_j \qquad (7.2)$$

MWS_i – the total amount landfilled in year i, t/year;

$MWS_{j,i}$ – content of component j in MSW in year i, % of the weight;

t – the index of the estimation year;

x – the period in years for which the data are entered;

$Lo_{\ j,i}$ – the potential of methane production in year i, t of CH_4/t of MSW, defined by the formula:

$$DOC_j \cdot DOC_F \cdot F \cdot 16/12 \cdot MCF_i , \qquad (7.3)$$

where: DOC_j – the total amount of organic carbon that can decompose biologically, for fraction j, tC/tMSW;

DOC_F – the proportion of carbon taking part in the decay reactions; F - content of methane in landfill gas, in shares, 16/12 – carbon to methane conversion factor;

MCF_i – methane correction factor for year i.

Methane emissions into the atmosphere are determined net of methane recovered or burnt in the flare in view of oxidation in the top layer:

$$Q(t)^{em} = [Q(t) - R] \cdot (1 - OX)\,, \tag{7.4}$$

where: R – collected methane, t; OX – the methane oxidation factor.

The model offers individual calculation for each category of organic waste (DOC_j, k_j), which are grouped according to the decomposition rate and their content of organic carbon. The national model does not account for the impact of activities on withdrawal of secondary material and energy resources from the "body" of dumping sites after MSW landfilling (so-called "landfill mining"). However, no opening of landfills for resource extraction was carried out in Ukraine [4].

7.2.2.2 Activity data

Transition to the multicomponent model led to the need to restore the series of data on the amount of MSW in Ukraine since 1900. To form a coherent set of data on the amount of waste that came to landfills and dumps in 1900-2004, statistical data on urban population in Ukraine (for 1900-1960 – [5], for 1961-2004 – data of the State Statistics of Ukraine) were used, as well as the specific waste accumulation standards for urban population according to reference books [6-11]. The proportion of waste forwarded directly to MSW dumps in the period of 1900-2004 was taken to be 85-90% [10]. Estimation of the mass of landfilled waste also includes the illegal MSW landfills. The share of the mass of landfilled waste consists 10-15% from collected and subsequently landfilled MSW [10].

In view of the fact that in the period of 2005-2006 national statistics in the field of MSW management was in the process of upgrading, the method of linear interpolation based on 2004 and 2007 data was applied to determine the mass of landfilled waste.

Since 2007, data on the weight of waste landfilled is taken directly from statistical reporting form No.1-TPV prepared by the Ministry of Communities, Territories and Infrastructure Development of Ukraine (MCTDIU), and further verified with data of regional housing and communal services administrations in the regions of Ukraine.

Data on the amount of industrial organic waste (medical waste, biological, paper and cardboard waste, wood waste, textile waste, animal and vegetable waste, animal waste produced in manufacture of food ingredients and products) transported to MSW dumps and containing organic matter able to decompose under anaerobic conditions for the years 2010-2021 were taken from the form No. 1 – waste "Waste Management" adopted as an element of mandatory reporting of companies in 2010. Data for the period of 1990-2009 were obtained with the substitution method using as the substitute statistical parameter the gross domestic product in percentage to 1990.

State Statistics Service of Ukraine (SSSU), which set an annual statistical form No. 1 – waste "Waste Management" to obtain data about generation and waste management aggregates all waste by: 1) hazard classes (I - IV)[9]; 2) materials according to List of waste categories by material; 3) operations management (recovery (R1-R11)/disposal (D1-D12)); 4) groups of waste by hazardous components [12].

Disposal of non-hazardous waste (IV class) allowed at landfills for municipal solid waste with the permission of the local sanitary-epidemiological and environmental services and fire inspection. That is, waste of IV class does not contain hazardous components and it's allowed to landfilled at

[9] Toxicological Classifier of Wastes: hazard class I – extra-hazardous; hazard class II – highly hazardous; hazard class III – moderately hazardous; hazard class IV - marginally hazardous. Wastes of hazard class IV are identified as non-hazardous temporary for international statistical comparison.

MSW landfills. Moreover, "The State building codes B.2.4-2-2005. Municipal Solid Waste Landfills. Basic design provisions" [13] contain the list of the industrial waste of IV hazardous class which accept on MSW landfills and use as isolating material (table 1, Annex J), the lists of the industrial waste of III-IV hazardous classes which accept on MSW landfills with restrictions (tables 2, 3, Annex J) [13].

Enterprises, institutions, organizations (any form of ownership), citizens - private entrepreneurs involved in generation and operations of industrial waste and classified/identified generated waste to I – III classes should be concluded contracts for transfer of waste with companies that have a license for hazardous waste management operations (collection, transportation, storage, processing, disposal). Toxic waste management involves the construction of several regional landfills for the centralized collection, treatment and disposal of toxic industrial non-recyclable waste.

According to Art. 26 of the Law of Ukraine "On Waste" [14], all waste is subject to state registration and certification. Waste certification provides preparation and maintenance of waste passports, passports of waste disposal sites, register maps of waste generation, treatment and disposal in accordance with the state classifier DK 005-96 "Waste classifier" and the waste nomenclature.

Waste management practice in Ukraine. According to the MCTDIU data 9-12 million tons of municipal solid waste are generated annually in Ukraine. In 2021, (according to official data of the MCTDIU) 10 418 million tons of MSW were disposed of in landfills and dumps. 642.6 kt of MSW were recycled and recovered due to the introduction of separate collection in 1725 settlements, 34 waste sorting lines, one waste incineration plant. Of them, 110.9 kt of MSW were incinerated, 911.8 kt were sent to secondary raw material collection points and waste recycling facilities and 8.8 kt were composted [15] (see Table 7.3). MSW disposal at the landfills and waste dumps remains the main approach for waste management in Ukraine. According to official data, more than 20-27 thousand unauthorized dumps are created each year. About 26.8 thousand unauthorized dumps were detected in 2021, and 25.5 thousands of them were liquidated. According to the received data, biogas extraction systems have been installed at 20 landfills in Ukraine. The amount of utilized biogas in 2021 amounted to 73.9 million m^3. More detailed information on the Landfill Gas Extraction is presented in the Section 7.2.2.4.

Table 7.3 The MSW management practices in Ukraine, 2021

MSW management	tons	%
Disposal to landfills	10 417649.7	91.0
Incinerated	110885.1	1.0
Processing and recycling	911775.1	7.9
Composted	8824.4	0.08

Source: MCTDIU [15]

In 2021, 79 % of population was covered by centralized MSW collection system in Ukraine which including all urban and partly rural areas. 21 % of population was not covered by centralized MSW collection in Ukraine which including to the largest part of rural areas. According to the official responses provided by the regional state administrations, MSW generated at the territories that are not covered by centralized MSW collection system was treated in the following way: self-organized MSW removal (often with the support of local rural authorities) at the containers' sites and landfills, the remaining generated MSW was thrown out at the dumps (illegally). MSW generated at all territories (urban and partly rural) covered by centralized MSW collection system and partly uncovered was temporarily stored in containers. Further, MSW stored in containers was transported to incineration facilities, sorting lines or directly to the landfills. In its turn, residue MSW from sorting lines was transported to incineration or composting facilities; the rest one was transported to the landfills.

Recycling. The system of preparation for re-use in Ukraine includes mainly waste sorting lines. As of 2021, 33 waste sorting lines operated in over 28 settlements, including 5 in Kyiv City [16]. Some of them are owned by providers of MSW collection service companies, some are installed at landfills. Most of the existing sorting lines in Ukraine process both commingled dry recyclables and residual waste, and rely mainly on manual sorting. The recycling levels are relatively low [17].

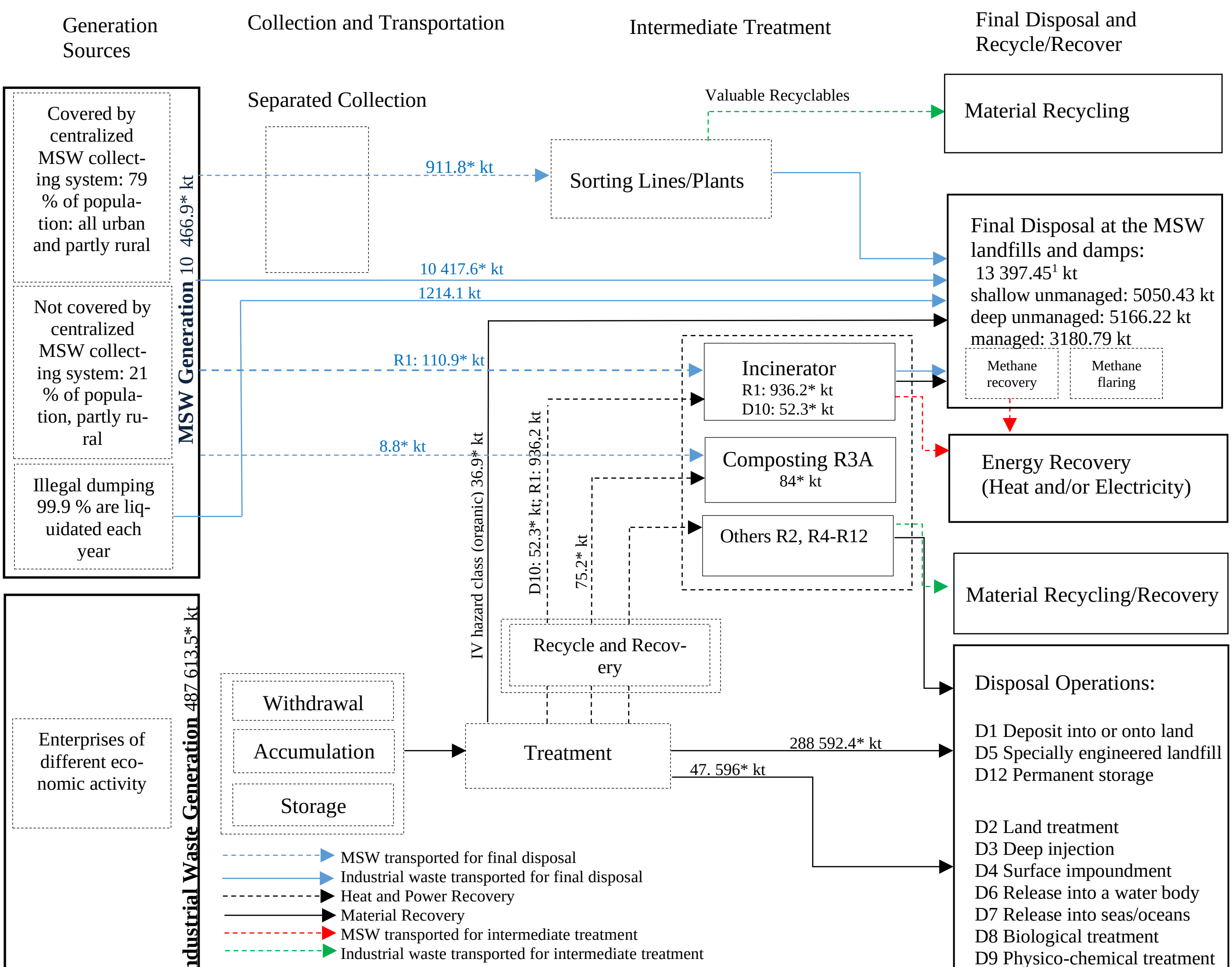
Currently, the effectiveness of using the recycling technique is at the stage of study in Ukraine. Besides, low tariffs on waste disposal services do not create incentives for businesses and local authorities to recycle waste. It is not only the lack of technology that impedes the proper processing of waste, but also the legislative lack of regulation. Moreover, to raise the level of recycling in Ukraine, the coverage of separate collection of MSW should to be significantly increased. However, separate collection fragmentarily covers a limited share of population settlements or includes containers for PET bottles only, sometimes for mixed recyclables with poor quality. As a part of the system for recyclables collection, there are points for procurement of secondary materials from the population. This activity does not require licensing, private companies or individuals can be owners of such points or their chains. There are recycling processing facilities for at least 100 secondary raw materials (paper, cardboard, glass, plastics, lead) in Ukraine. According to the experts, recycling facilities work under designed capacity due to the unstable and insufficient supply of resource-containing materials. The best situation is in the field of paper/cardboard recycling, but stable supply of secondary raw materials is ensured by imports. A significant volume of resource-valuable components is delivered by the 'informal sector' after extraction from containers for mixed waste [17].

The only attempt to start the waste recycling plant with the announced Refuse Derived Fuel (RDF) production proved to be unsuccessful in 2013 mainly due to insufficient technical solutions and the absence that time special tariff for solid waste treatment. Plans for the construction of various waste treatment facilities have been announced periodically over the past twenty years. Currently, there are real plans to introduce mechanical-biological treatment (MBT) technology in L'viv and Khmelnitsky [18].

Composting. Composting of MSW is still not common practice in Ukraine. The overall level of MSW composting is low as soon as only 8824.4 tons (0.08 % of the MSW collected) of waste were composted in 2021 by official data of the MCTDIU. Today there is an example of a new successful commercial full-scale composting project in Lviv.

Incineration. At the beginning of the 1980s, four MSW incineration plants were built in the cities of Kharkiv, Dnipropetrovsk, Kyiv and Sevastopil (ARC). The total designed capacity of these plants was about 1.2 million tons per year. Three of these incineration plants were closed as a result of noncompliance with the Ukrainian environmental standards. Currently, only one incineration plant 'Energia' in Kyiv City with the capacity of 250 000 tons per year and 3 incineration installations in Kharkiv City and Kharkivska Oblast are in operation. The incineration plant 'Energia' is managed by Kyivenergo and produces heat for district supply purposes. Despite there are no calculations to exactly define this process as a recovery or disposal operation, incineration is formally considered as recovery operation because of the production of heat used by two residential districts of Kyiv City. The capacity of the enterprise allows incinerating more than 20 % of MSW generated in Kyiv [17]. The State Statistics Service of Ukraine provides information on the incinerating of industrial waste by incinerators. There is currently no information on the types and technologies incineration of waste incinerators. Available data only on the capacity of waste incineration plants. According to SSSU in 2021 more than 52,3 kt of industrial waste were incinerated without energy recovery (as a disposal operation) by 77 incinerators. These data are not complete, because 20 % of respondents did not provide information, as noted by the SSSU.

The acting waste management legislation is partly out-of-date. Presently it is based on the Law "On Waste" (LW, 1998) [14] which is planned to be replaced as soon as possible. To facilitate transformation processes on the basis of EU principles and practices, the National Waste Management Strategy up to 2030 was approved by the Cabinet of Ministers of Ukraine in 2017 [19] as well as National Waste Management Plan up to 2030 was also approved in 2019 [20]. This document will support the successful implementation of the Waste Management Strategy. In general, the Waste Management Strategy includes three phases, each of them is directed to resolve a number of specified issues taking into account the current state of waste treatment in Ukraine. On June 20, 2022, the Law of Ukraine "On Waste Management" on implementation of EU requirements in waste treatment system was adopted [21]. The law involves the implementation of waste hierarchy principles, extended producer's responsibility, electronic licensing system, and also implying changes in waste classification and accounting system. The document is in the process of entering into force.



*according to official statistic;
[1] including illegal dumping, organic industrial waste (IV class), official landfilling and occupied territories

Fig. 7.3. Waste management practices in Ukraine, 2021

7.2.2.3 Selection of emission factors

Methane correction factor (MCF). Estimation of the *MCF* value characteristic of Ukraine was performed based on an expert opinion[10] issued for 1990-2009, which indicates distribution of MSW flows by different types of landfills and dumps – managed, unmanaged deep, and unmanaged shallow ones.

According to the expert opinion a substantial portion of MSW landfills in Ukraine are dumps formed spontaneously in the 60-70's in place of clay or sand pits, in ravines or on flat sites of surface in the immediate vicinity of city limits. As a result, dumps located near cities with population of 50 thousand people or more are sites with the depth of 5-10 meters of waste and classified [1] as unmanaged deep landfills *(MCF* = 0.8). Dumps formed around settlements with population of less than 50 thousand do not reach the depth of 5 meters, and under classification [1] they can be attributed to unmanaged shallow landfills *(MCF* = 0.4). Besides, there are sites in Ukraine that can claim the status of managed ones *(MCF* = 1.0). These are engineering constructions, reconstruction of which began in the late '80s (after more stringent standards for operation of landfills were adopted) and was completed in 1990 in the following cities: Kyiv, Kharkiv, Dnipropetrovsk, Luhansk, Cherkasy, Chernivtsi, Ivano-Frankivsk, Lutsk, Yalta.

[10] Yu. Matveev, senior researcher at the Institute of Engineering Thermophysics of the National Academy of Sciences of Ukraine, deputy director of the Scientific and Technical Center "Biomass", 2011.

Thus, waste generated in cities with population of less than 50 thousand people were attributed to unmanaged shallow landfills, above – to unmanaged deep, in the above large cities – to managed deep ones started from the 1990. For the period from 2010, MSW distribution by type (excluding industrial waste and unofficially dumped) of dumps was taken to be the same as for 2009. This approach is valid due to the fact that since 2010 activities on commissioning of new landfills have been virtually been suspended, which, in turn, is caused by the stricter rules for construction of new landfills adopted in 2010.

For detailed data on distribution of flows of solid waste by landfill types in 1990-2021, see Table 7.4, on the amount of landfilled waste by different types of landfills in 1990-2021 – Annex 3, Table A3.4.1.

Table 7.4. Distribution of MSW flows by their landfilling sites

Year	Dumps and landfills			MCF_{av}
	Unmanaged shallow*	Unmanaged deep*	Managed*	
1990	0.370	0.616	0.014	0.655
1991	0.371	0.601	0.028	0.657
1992	0.371	0.587	0.042	0.660
1993	0.372	0.571	0.056	0.662
1994	0.375	0.554	0.071	0.664
1995	0.375	0.540	0.085	0.667
1996	0.375	0.525	0.100	0.670
1997	0.375	0.510	0.114	0.673
1998	0.375	0.496	0.129	0.676
1999	0.375	0.482	0.143	0.679
2000	0.375	0.468	0.157	0.682
2001	0.374	0.455	0.172	0.685
2002	0.373	0.441	0.186	0.688
2003	0.372	0.428	0.200	0.691
2004	0.371	0.415	0.214	0.694
2005	0.371	0.400	0.228	0.697
2006	0.373	0.398	0.229	0.696
2007	0.369	0.401	0.229	0.698
2008	0.368	0.401	0.231	0.699
2009	0.370	0.398	0.233	0.699
2010	0.368	0.400	0.232	0.699
2011	0.370	0.396	0.233	0.699
2012	0.373	0.391	0.235	0.698
2013	0.376	0.386	0.237	0.697
2014	0.375	0.389	0.236	0.697
2015	0.371	0.396	0.234	0.698
2016	0.377	0.385	0.237	0.697
2017	0.377	0.385	0.238	0.697
2018	0.371	0.395	0.234	0.698
2019	0.377	0.385	0.237	0.697
2020	0.376	0.387	0.237	0.697
2021	0.377	0.386	0.237	0.697

* MSW shares disposed in dumps and landfills of different types

MSW composition (MWS_j). The waste composition data were available for the years 1990, 2006 and 2011. For 1990, the shares of waste components were taken from [10]. For 2006 the shares of waste components were taken based on the data of research on the morphological composition of waste in six cities of the country – Yevpatoria, Simferopol, Yalta, Kharkiv, Kyiv and Donetsk conducted in 2000-2004. For 2011, the shares of waste components were estimated by analyzing and systematizing data research on the morphological composition of waste in 22 cities of Ukraine conducted in 2008-2013 and data on the morphological composition of waste provided by regional state administrations. The results of this analysis presented on paper [3]. The analysis was carried out on seven biodegradable components: paper and cardboard (I), textiles (II), food waste (III), wood (IV), garden and park waste (V), personal care products (VI), rubber and leather (VII). The MSW composition was calculated based on the amount of MSW landfilled in the regions, and missing source data – based on assumptions agreed with experts in the field of MSW management:

- unsorted organic components contain up to 15 % of gardens and up to 25 % of food waste;
- the component "bone, leather, and rubber" by 1/3 consists of bones (in the absence of direct measurement data);
- the share of personal care products is determined as the sum of imports and production minus exports of this commodity group in the reporting year;
- MSW composition in the regions is determined as the arithmetic mean of data in cities located in this region;
- in the regions where the studies have not been conducted, data on the morphological composition are determined as the average of the data in the neighboring regions [3].

In recent years, no systematic research on the morphological composition of waste has been conducted, only in certain cities under some recent projects funded by International Financial Institutions (IFIs), in particular [22, 23, 24]. According to IFC, in comparison of the MSW generation structure in Ukraine to that in the EU countries, experts conclude it is closer to Eastern European countries (Poland, Czech Republic, Slovakia, Baltic States, etc.). The organic fraction in Ukraine is greater than that in other European countries, while the shares of glass and plastic are relatively low [23]. A comparison of the disposed waste composition between European countries is presented in Table 7.5

Table 7.5. Comparison of the disposed waste composition between European countries

Countries	Paper	Textile	Rubber	Wood	Food	Garden	Personal care	Other
Ukraine	13.72	3.89	1.86	1.75	31.84	3.64	1.4	41.9
Poland[1]	14.89	3.73	-	0.61	36.40	0.31	-	44.06
Latvia[1]	6.40	3.35		2.11	47.9	-	-	31.69
Romania[1]	11.6		-	1.95	36.62	14.84	-	-
Eastern Europe	21.8	4.7	1.4	7.5	30.1	-	-	34.4

[1] National Inventory report 2021

[2] 2006 IPCC Guidelines (vol. 5, section 5.3.1, table 2.3)

The missing data of waste composition for the remaining years 1991-2005, 2007-2010 were estimated by linear interpolation. The MSW composition for 2014-2021 was adopted based on the data for 2013. For the more detailed composition of MSW in 1900-2021, see Fig. 7.4 as well as Table A3.4.2 of Annex.

The content of biodegradable carbon (DOC_j). The model uses default *DOC* values for all the components to 2006 IPCC Guidelines [1] (see Table 7.6).

In 2012, the field and laboratory experiments on DOC determination in food waste were carried out [25]. The results have shown that DOC for food waste probably may be much lower than the IPCC 2006 default value but taking into account the singularity and non-systematic character of the study an additional activity is needed to develop national coefficient.

The methane production rate constant k_j is taken by default for the temperate climate zone according to [1] and presented in Table 7.6.

Table 7.6. *DOC* and *k* values for biodegradable MSW components

#	Component	The constant rate of methane production *(k)*, year $^{-1}$	Biodegradable carbon *(DOC)*
I	Paper and paperboard	0.048	0.40
II	Textile	0.048	0.24
III	Food waste	0.110	0.15
IV	Wood waste	0.024	0.43
V	Garden and park waste	0.070	0.20
VI	Personal care products	0.048	0.24
VII	Rubber and leather	0.048	0.39

The share of actually decomposed organic carbon (DOC_F). The DOC_F value is the default one [1] and equal to 0.5.

Methane content in landfill gas (F). The F value is the default one [1] and equal to 0.5.

The delay time (t_0). The value of t_0 is 6 months [2].

Methane oxidation factor (OX). In Ukraine, there is no evidence documenting the degree of methane oxidation in landfills, so the default value of 0 [2] was used.

Fig. 7.4. Content of biodegradable MSW components for the period of 1900-2021, % to weight. For the meaning of I-VII, see Table 7.5.

7.2.2.4 Methane utilization at MSW dumps

Utilization of methane from MSW dumps in Ukraine started in 2003. By this year, as part of a demonstration project of Ekolins program at the municipal MSW landfill of Luhansk the companies SCS Engineers (USA) and SEC "Biomass" (Ukraine) had performed work to install the landfill gas collection system consisting of three vertical holes. Landfill gas was collected and burned in the open flare during 2003, 2004, and 2006.

Since the beginning of the commitment period under Kyoto Protocol (2008), Ukraine commissioned industrial degassing systems at MSW landfills, which were built in the framework of joint implementation projects under flexible financial mechanisms of Kyoto Protocol.

In recent years, such methane collection and utilization systems are becoming more widespread in Ukraine. Thus, while in 2008 there were only two such operating systems, in 2011 only "Alternative Environmental Protection Energy Systems and Technologies" company, Ltd commissioned the biogas collection systems at the landfills of the cities of Kremenchuk, Vynnytsya, and Zaporizhya. Almost all recovered landfill gas was burned on flares.

In 2012, electricity was generated from landfill gas on the industrial scale for the first time in Ukraine. "LNK" company, Ltd put into operation a biogas collection system with subsequent electricity generation at the MSW landfill in Kyiv in 2012, in Boryspil – in 2013, in the Brovary – in 2014. In 2017 in Cherkasy region, the Caterpillar CG132-12 gas piston power generating facility with an electrical power of 600 kW was commissioned. At present, "LNK" company, Ltd put into operation seven degassing complexes: Obukhiv, Kyiv region – 2 modules (total power 2,126 kW); Boryspil, Kyiv region – 1 module (total power 1063 kW); Brovary, Kyiv region – 1 module (total power 1063 kW); Zhytomyr, Zhytomyr region – 1 module (total power 1063 kW); Mykolaev, Mykolaev region – 1 module (total power 1063 kW); Cherkasy, Cherkasy region – 1 module (total power 600 kW). To monitor the chemical composition of biogas, the company uses Geotech portable gasanalyzers made in Britain, Biogas 2000, Biogas 5000, GA 5000. All devices are certified according to international standards ISO 9001: 2015, SIR A 01 ATEX 092, British standard, UKAS №4533. Electric power measurement is carried out by meters as ZMD405CR44, ZMD405CT44 "Landis + Gyr (Pty) company, Ltd", Switzerland, have certificate G3-PLC, ITU G.9903.

Since 2012, the main objective of biogas recovery from solid waste has not been the reduction of greenhouse gas emissions, but generation of electricity which is sold at a "green" tariff. At the state level, a number of legislative acts aimed at the development of the biogas industry have been adopted, with a "green" tariff set for the sale of electricity produced by the biogas plant. Accordingly, utilization of methane at landfills is carried out mainly for the purpose of electricity production. The production and sale of electric energy from biogas is subject to licensing in a compulsory manner. The license for electricity production, as well as the "green" tariff for each specific station, is approved by the Energy and Utilities National Regulatory Commission, Ukraine (EUNRCU). The official site of the Commission provides information on companies (subjects) and their facilities (objects) of alternative energy, which have a "green" tariff, including companies-producers of electricity from biogas.

Moreover, the amount of utilized (recovered) methane from the MSW landfills is fixed in the form No. 4-MTP (provided by the State Statistics Agency) as a component of the total amount of fuel consumption for conversion into heat and electric energy. And it is taken into account in the "Energy" sector in the category 1.A.1.c. It cannot be deducted due to absence of additional information. According to the Guidelines [1], if the recovered gas is used for energy, then the resulting greenhouse gas emissions should be reported under the "Energy" sector.

The amount of recovered methane in MSW dumps in Ukraine for the period of 2003-2021 is present in the Table 7.7 and shown in Figure 7.5. Since 2008, this figure had been rising annually – from 0.15 tons to 13.37 tons in 2014. However, since 2012, the amount of flared methane has been gradually decreasing, apart from the recovered methane, which has been increasing. A sharp reduction of flared methane was observed from 2016 due to the change of biogas utilization goal, namely electricity production and its sale at a green tariff. According to EUNRCU data there were 6 companies producing electricity from biogas and 14 units on the landfills in Ukraine in 2017; 9 companies and 20 units on the landfills in 2018; 11 companies and 26 units in 2019. According to experts, biogas extraction systems have been installed at 26 landfills in 2020. Not all companies provided requested data. Thus, Table 7.7 presents information only those companies that provided data on the number of installed biogas collection systems, the volumes of landfill gas flared/recovered and amount of methane flared/recovered.

Table 7.7. Methane utilization at MSW landfills in Ukraine

years	Biogas collection systems installed	Biogas collected		Emission reduction		Emission reduction
		Flaring, mln. m^3	Recovery, mln. m^3	Flaring, Kt	Recovery, kt	Total, kt
2010	3	0.903	0.000	2.314	0.000	2.314
2011	8	4.206	0.000	4.566	0.000	4.566
2012	6	14.072	3.105	8.279	1.755	10.034
2013	6	11.065	7.087	6.583	3.992	10.575
2014	7	11.544	11.431	6.907	6.459	13.365
2015	8	4.311	17.439	2.631	5.606	8.236
2016	7	0.167	22.699	0.105	7.655	7.759
2017	11	0.053	30.297	0.031	16.332	16.364
2018	15	0.030	44.713	0.018	22.216	22.234
2019	16	0.023	47.347	0.013	25.302	25.315
2020	19	0.041	63.001	0.022	35.516	35.538
2021	20	0.000	73.877	-	39.390	39.390

The volumes of utilized methane were calculated based on data of MSW landfill operators on the monthly volume of landfill gas utilization, its density, and the content of methane with the one-digit distribution of reclaimed landfill gas into volumes burned in the flare or recovered with electricity production under the formula:

$$R^{Fl,Rec} = V_R \cdot \rho_{LG} \cdot \gamma_m \cdot 10^{-6} , \qquad (7.5)$$

where: $R^{Fl,Rec}$ is the mass of methane burned in the flare/recovered, thousand tons;
V_R - volume of landfill gas burnt in the flare/recovered, m^3;
ρ_{LG} - landfill gas density, kg/m^3;
γ_m - methane content in landfill gas, % to weight.

Methane content in landfill gas ranges from 30-58 % at different landfills for different years; landfill gas density is 1.26-1.3 kg/m^3; the volumes of landfill gas flared/recovered in 2021 amounted to 73877955.4 m^3 according to the data provided by the companies. Thus, according to collected data 39.39 kt of landfill methane were recovered and 0.0 kt were flared in 2021 (see Fig. 7.5).

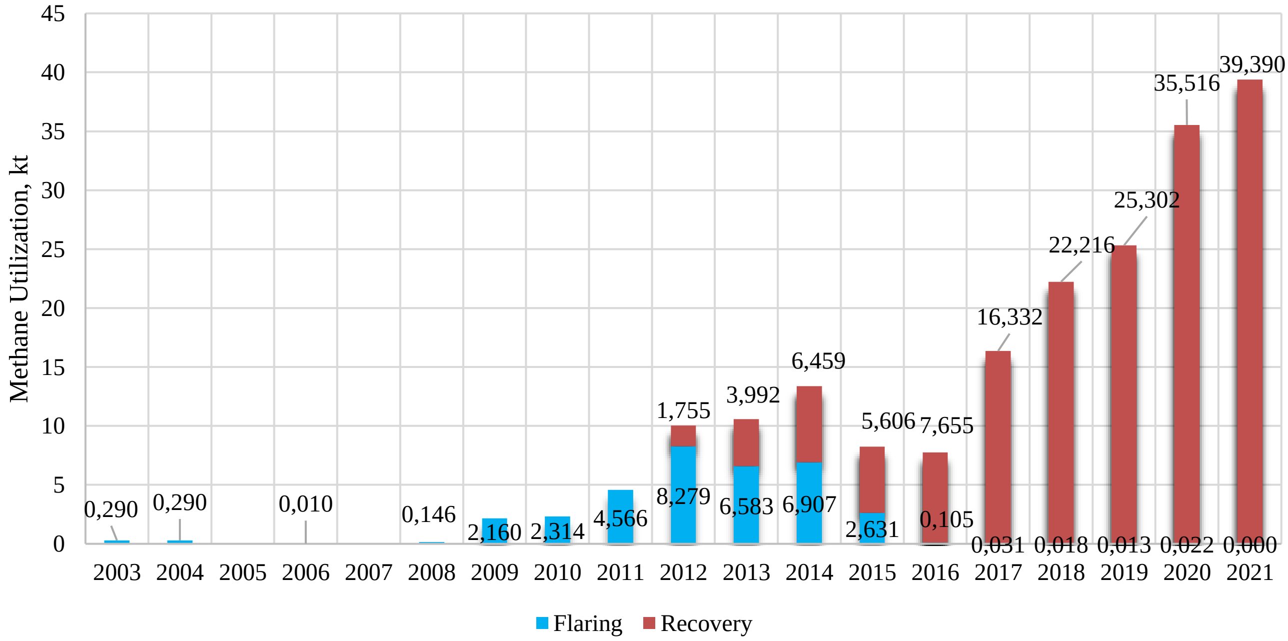


Fig. 7.5. Methane utilization at MSW landfills in Ukraine, 2003-2021

7.2.2.5 Carbon stored at MSW dumps

The carbon that is long stored in MSW dumps, which is part of paper, cardboard, wood and garden and park waste, in accordance with section 3.4 of [1] is accounted for as information in the "Waste" sector and estimated for different types of dumps according to the formula:

$$DOCm\ LS_T = W_T \cdot DOC \cdot (1 - DOC_F) \cdot MCF\ , \qquad (7.6)$$

where: $DOCm\ LS_T$ is carbon in the composition of paper, cardboard, wood, and garden and park waste disposed in the MSW dump in the reporting year, thousand tons.

W_T – the weight of paper, cardboard, wood, and garden and park waste disposed in the MSW dump in the reporting year, thousand tons;

DOC – the total amount of organic carbon contained in paper, cardboard, wood and garden and park waste, tC/tMSW (the specified ingredients);

DOC_F – the fraction of carbon taking part in decay reactions;

MCF – methane correction factor for different types of dumps.

When assessing the amount of carbon stored for a long time in MSW dumps, data on disposal of waste since 1900 were used. Data on the weight of landfilled components are presented in Annex 3.4, on categories of different types of dumps – in Table 7.3, on *DOC* content in MSW components – in Table 7.4.

Fig. 7.6 presents results of the estimations for the period of 1990-2021.

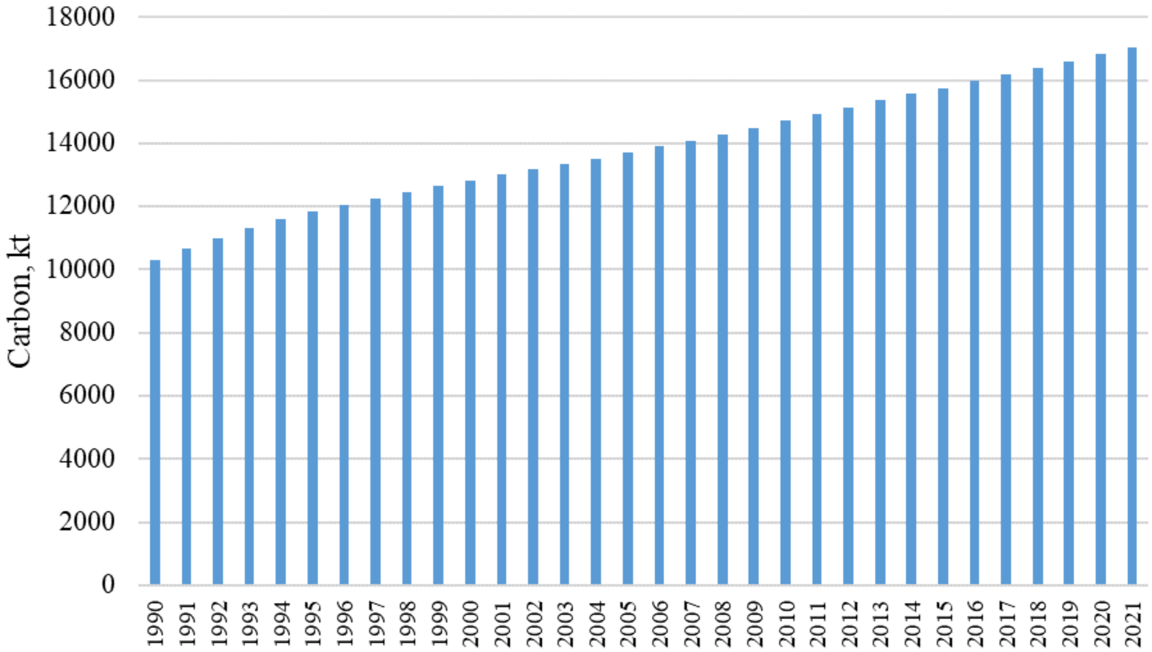


Fig. 7.6. Accumulated long-term storage carbon at MSW dumps, 1990-2021

7.2.3 Uncertainties and time-series consistency

The range of uncertainty estimates for activity data and emission factors was analyzed in paper [2] in accordance with [1]. See Table 7.8.

Table 7.8. The range of uncertainty estimates

Parameter	Estimated uncertainty	
	"-"	"+"
Activity data		
Mass of MSW dumped		
Managed landfills	*10*	*10*
Unmanaged landfills	*30*	*30*

Parameter	Estimated uncertainty	
	"-"	"+"
Uncertainty of activity data		
Managed landfills	10	10
Unmanaged landfills	30	30
Emission factors		
Waste composition	10	10
Biodegradable carbon (DOC)	20	20
The share of actually decomposed organic carbon (DOC_F).	20	20
Methane correction factor (MCF)		
Managed landfills	*10*	*0*
Unmanaged shallow landfills	*30*	*30*
Unmanaged deep landfills	*20*	*20*
Methane content in landfill gas (F)	5	5
Methane recovery (R)	3	3
Oxidation factor, OX	Not included into the analysis	
The constant rate of methane generation (k)	20	20
Uncertainty of CH_4 emission factors for managed landfills	37.87	36.52
Uncertainty of CH_4 emission factors for unmanaged shallow landfills	47.27	47.27
Uncertainty of CH_4 emission factors for unmanaged deep landfills	41.64	41.64
The standard uncertainty of CH_4 emissions for managed landfills	**39.17**	**37.87**
The standard uncertainty of CH_4 emissions for unmanaged shallow landfills	**55.98**	**55.98**
The standard uncertainty of CH_4 emissions for unmanaged deep landfills	**51.32**	**51.32**

7.2.4 Category-specific QA/QC procedures

For estimation of emissions in the category, general quality control and assurance procedures were applied. Since methane emissions from MSW landfills is a key category, expert estimates of emissions were used for QA/QC, and the following procedures:

- ✓ comparison of activity data from different sources;
- ✓ comparison of emission along the time series and analysis of activity data trends;
- ✓ comparison of activity data, emission factors, and estimation results with inventory reports of other countries.

The national multi-component model for calculating methane emissions from MSW disposal sites in Ukraine was discussed with national experts in the field, as well as with representatives of the international research community from 24 countries at the Seventh International Conference "Energy from Biomass", September 2011. Moreover, the results of GHG emission estimations for the period of 1990-2010 in the category, as well as raw data, the methods of their processing, and emission factors were presented at the 9th International Conference "Cooperation for Waste Issues", March 2012.

7.2.5 Category-specific recalculations

In this sub-category, recalculations were made due to the obtaining additional data on methane recovery at the landfills for 2020 year. Results of recalculation are provided in Table 7.9.

Table 7.9. Recalculations in subcategory 5.A "Solid Waste Disposal"

Year	Inventory Report, 2022 submission, kt			Inventory Report, 2023 submission, kt			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
2020	-	309.21	-	-	308.13	-	-	-0.35	-

7.2.6 Category-specific planned improvements

See Table A8.2 Improvement Plan for the NIR.

7.3 Biological Treatment of Solid Waste (CRF category 5.B)

7.3.1 Category description

In this category, CH_4 and N_2O emissions from composting of waste in Ukraine are estimated. The category accounts for emissions from composting of all types of waste (including industrial, household, and the like) for the exception of waste, treatment of which should be taken into account in accordance with [1] in the "Agriculture" sector, namely: excrements of farm animals. GHG inventory was held under Tier 1 using the default emission factors based on the raw data provided by the Statistics of Agriculture and the Environment Department of the State Statistics Service of Ukraine.

GHG emissions in this category in the reporting 2021 amounted to 17.58 kt of CO_2-eq., including: 0.37 kt of CH_4 and 0.03 kt of N_2O, the decrease with respect to 1990 (34.36 kt of CO_2-eq.) is 48.8 % and increase with respect to previous year is 134.6 % (see Fig. 7.7).

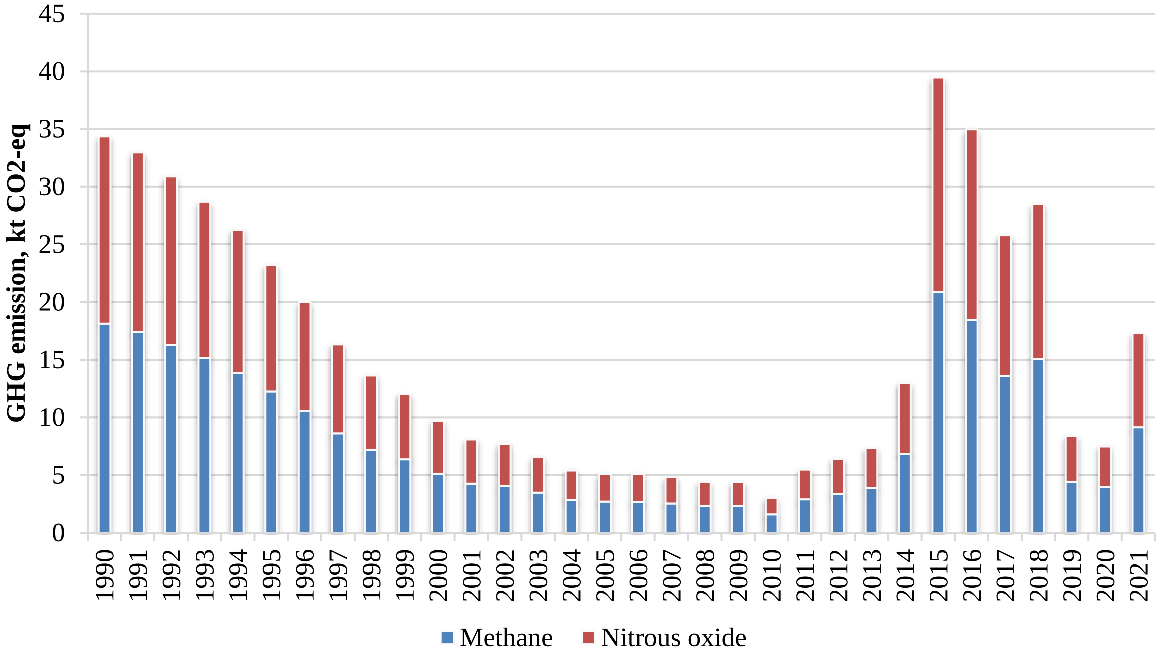


Fig. 7.7. GHG emissions from waste composting in Ukraine, 1990-2021

Since 1990, emissions have been steadily dropping, and by 2010 reduced 11.3 times. This trend is due to a decrease of production in the agricultural sector and, as a consequence, a reduction of the resource base for production of compost. Since 2010, GHG emissions in the category began to increase due to modernization of individual agricultural enterprises. Significant GHG emissions increase in 2015 compared to the previous year was caused by the increase of composting agricultural waste amount in food processing industry.

7.3.2 Methodological issues

7.3.2.1 General principles

According to [1], in the process of waste composting most of *DOC* in the waste material is converted to CO_2. CH_4 is formed in anaerobic compost sites, but in most cases, methane is oxidized in the same sites of compost. CH_4 emissions getting into the atmosphere that are subject to estimation range from less than one percent to a few percent of the total carbon content in the material [26-28]. Composting may also result in emissions of N_2O. The range of estimated emission ranges from 0.5 percent to 5 percent of the total nitrogen content of the material [29].

According to [1], CO_2 emissions from composting of biogenic waste components (garden and park, communal, agricultural ones, etc.) are not accounted for.

Emissions of CH_4 and N_2O can be estimated with equations (7.7) and (7.8):

$$Q_{CH_4} = M \cdot EF_{CH_4} \cdot 10^{-3} - R, \tag{7.7}$$

where: Q_{CH_4} is the total amount of CH_4 emissions in the reporting year, thousand tons;
M - the mass of organic waste undergoing composting, thousand tons;
EF - the emission factor for composting of waste, g of CH_4/ kg of composted waste;
R - the total amount of recovered CH_4 for the reporting year, thousand tons of CH_4;

$$Q_{N_2O} = M \cdot EF_{N_2O} \cdot 10^{-3}, \tag{7.8}$$

where: Q_{N_2O} is the total amount of N_2O emissions in the reporting year, thousand tons;
M - the mass of organic waste undergoing composting, thousand tons;
EF_{N_2O} - the emission factor for composting of waste, g of N_2O/ kg of composted waste.

7.3.2.2 Activity data

As of 2015, accounting of waste composting in Ukraine was conducted in accordance with two reporting forms:

- "No.1 – TPV" (Ministry of Communities and Territories Development of Ukraine)
- "No.1 – waste" (State Statistics Service of Ukraine).

Form "No.1 – waste" includes information on all the waste that is composted in Ukraine, data on the type of waste is submitted directly from the enterprises. Form "No.1 – TPV" contains information on MSW composting, which should be included in the form "No.1 – waste". However, there was some inconsistency on the data of MSW composting presented in forms. The amount of MSW composting presented in the form "No.1 – TPV" is much significant than that presented in the "No.1 – waste". Thus, it was decided to summarize the data on MSW composting of two forms for the period 2015-2021. The data on the amount of waste composting based on the form "No.1 – waste" presented in the Table 7.10

The analysis of primary data on waste composting has shown the existing information on enterprises level for 2012 is not full and doesn't reflect the trend. In this connection, interpolation on waste composting was performed for 2012 based on the data for 2011 and 2013.

At *stage I,* a number of obvious errors related to filling form "No.1 – waste" directly by enterprises were ruled out.

At *stage II,* the data were aggregated with DK 005-96 classification (the state waste classifier) by waste types, as recommended in [1].

At *stage III,* the missing time series for 1990-2009 on composting of waste in Ukraine was restored.

According to results of *stage I,* the mass of composted waste in Ukraine in 2010 amounted to 147.4 kt (74 enterprises), in 2011 - 196.0 kt (91 enterprises), in 2012 - 310.6 kt, in 2013 - 357.7 kt

(114 enterprises), in 2014 - 687.0 kt (118 enterprises), in 2015 – 672.0 kt (123 enterprises), in 2016 – 726.5 kt, in 2017 – 776.1 kt (154 enterprises); in 2018 – 682.1 kt (141 enterprises); in 2019 – 634.4 kt (126 enterprises); in 2020 – 567.7 kt (92 enterprises); 2021 – 610.6 kt.

Based on results of *stage II*, the source data were grouped as 7 categories: bird droppings (I); feces, pus, and urea (II); crop residues (straw, etc.) (III); other vegetable oils and animal (IV); household and similar waste (V), wood waste (VI), other waste (VII). This classification meets GHG inventory principles in accordance with [1], as to avoid double counting emissions from composting of waste categories I-II should be accounted for in the "Agriculture" sector.

Waste composting data on Table 7.10 presents data on waste composting in Ukraine based on results of *stage II* of raw data processing.

Table 7.10. Waste composting in Ukraine, 2010-2021, tons

Category	Bird droppings	Feces, pus, and urea	Plant residues (straw, etc.)	Other vegetable and animal residues	Household and similar waste	Wood waste	Other waste	Total: I-VII / III-VII
Designation	I	II	III	IV	V	VI	VII	
DKV code	0124.2.6.03	0121.2.6.03	1583.1.1.02, 0111.3.1.01, 0111.2.9.02, 1561.2.9.04, 0112.2.9.01, 0112.3.1.02	0111.2.6.02, 1590.2.9.01, 0111.1.1.01, 0113.1.1.01, 1910.2.9.03	5200.3.1.03, 1589.3.1.05	2000.2.2.17, 7760.3.1.03, 0113.2.9.01, 2000.2.2.16	1583.2.9.03, 9030.2.9.05, 7720.3.1.02, 1590.2.9.15, Other	
2010	42107.8	89322.8	3375.7	2301.2	313.8	188.7	9836.1	147446.2 / 16015.6
2011	62604.3	104411.3	3734.1	3353.4	9993.8	483.7	11412.0	195992.6 / 28976.9
2012	43307.2	233425.7	2351.9	8553.4	6825.0	248.8	15852.7	310564.8 / 33831,9
2013	60473.5	258515.7	969.8	13753.4	3656.2	13.9	20293.5	357676.1 / 38686.8
2014*	256610.3	361819.1	369.2	59944.5	17.2 / 3215.7[1,2]	2874.4	2089.7	686940.3 / 68510.9
2015*	15888.1	447706.9	4937.4	154700.4	3.6 / 2772.1[1]	6593.9	39422.4	672024.9 / 208429.8
2016*	35946.7	505833.5	746.2	27868.9	36.4 / 1623[1]	11336.6	143091.6	726482.9 / 184702.7
2017*	38454.9	601447.8	801.3	94915.6	14.1 / 973.8[1]	7364.8	32160.8	776133.2 / 136230.5
2018*	21611.5	509877.9	247.3	106884.7	14.2 / 1640.2[1]	8567.6	33215.8	682059.3 / 150569.9
2019*	13456.1	576606.4	265.3	18297.1	17.4 / 1192[1]	9307.9	15267.4	634409.6 / 44347.0
2020*	62.64	528078.0	246.7	11720.1	13.4 / 6201.5[1]	20220.9	95.57	567695.4 / 39554.7
2021*	46.98	528062.0	203.9	16617.8	2288,4 / 8824.4[1]	19994.0	43368.6	610581.7 / 91297.2

*data of the State Statistic Service of Ukraine (form "No.1 – TPV"), corrected using analytical study [36];
[1] MSW composting data provided by the Ministry of Communities, Territories and Infrastructure Development of Ukraine (form "No.1 – TPV");
[2] data interpolated

According to results of *phase III*, the time series of waste composting in Ukraine for categories I-VII for 1990-2009 was restored (see Table 7.11).

When assessing data for all categories of waste, the following assumptions were proposed:

- The weight of composted category I waste is directly proportional to the amount of litter produced during the reporting year, which in turn is estimated based on the bird population.

- The weight of composted category II waste is directly proportional to the amount of feces, pus, and urea produced during the reporting year, which in turn is estimated based on the cattle and pig population.
- The share of composted waste of categories III, IV, VI, and VII in the total weight of composted waste is constant.
- The weight composted waste of category V is directly proportional to the amount of MSW generated and dumped during the reporting year.
- When restoring the time series for 1990-2009, the basic values were set as average values of the indicators in the period of 2010-2013.

Table 7.11. SW composting in Ukraine, 1990-2009

Year	Solid Waste Category								
	Tons								
	I	II	III	IV	V	VI	VII	I+II	III+IV+V+VI+VII
1990	67674.9	1645666.6	19536.8	52368.1	248.5	1751.4	107491.8	1713341.5	181396.6
1991	64241.7	1579629.8	18744.7	50244.9	242.5	1680.4	103133.6	1643871.5	174046.1
1992	57211.1	1483067.4	17563.5	47078.9	236.4	1574.5	96635.0	1540278.5	163088.3
1993	46221.6	1385276.4	16323.3	43754.3	229.9	1463.3	89810.9	1431498.0	151581.6
1994	36236.3	1272650.1	14925.3	40007.0	221.9	1338.0	82119.1	1308886.4	138611.1
1995	28614.5	1129195.6	13202.7	35389.7	212.6	1183.6	72641.6	1157810.1	122630.2
1996	21244.0	975620.4	11367.7	30470.9	203.0	1019.1	62545.0	996864.5	105605.6
1997	15664.8	797254.1	9270.6	24849.7	213.3	831.1	51007.0	812918.9	86171.6
1998	14936.4	664080.8	7744.1	20757.9	223.5	694.2	42608.1	679017.2	72027.9
1999	14423.3	584453.9	6830.5	18309.1	233.5	612.3	37581.6	598877.1	63567.1
2000	12976.8	469484.5	5503.4	14751.7	243.1	493.3	30279.6	482461.3	51271.1
2001	14678.1	386921.9	4581.6	12280.8	252.3	410.7	25207.8	401600.0	42733.1
2002	18705.1	362683.6	4351.2	11663.4	261.2	390.1	23940.5	381388.6	40606.4
2003	20146.5	305498.2	3715.8	9960.1	271.0	333.1	20444.4	325644.7	34724.4
2004	21833.9	244701.5	3042.0	8154.0	281.2	272.7	16737.1	266535.4	28487.0
2005	27518.6	223966.3	2870.7	7695.0	310.6	257.3	15794.9	251484.9	26928.6
2006	32568.5	218867.2	2870.1	7693.3	304.4	257.3	15791.4	251435.8	26916.5
2007	35573.0	201757.3	2709.2	7262.0	298.2	242.9	14906.2	237330.2	25418.5
2008	39166.7	178668.9	2487.0	6666.3	297.8	222.9	13683.3	217835.6	23357.3
2009	43817.1	172770.4	2472.9	6628.5	310.8	221.7	13605.8	216587.5	23239.7

7.3.2.3 Selection of emission factors

Research on development of composting of organic waste components started back in the Soviet Union, in the late 1920's. Nevertheless, to this day no high-tech waste composting system has been established in Ukraine, and composting is held mainly in semi-haphazard compost pits.

Thus, there is no information on Ukraine-specific GHG emission factors for waste composting, so the values of emission factors were taken by default for the wet substance: 4g of CH_4/kg of waste and 0.3 g of N_2O/kg of waste; and they are presented in Table 7.12, which corresponds to Table 4.1 of 2006 IPCC Guidelines [1].

Table 7.12. CH_4 and N_2O emission factors for composting

Emission factors CH_4		Emission factors N_2O		Notes
based on dry substance	based on wet substance	based on dry substance	based on wet substance	Assumptions for composted waste: 25-50% of DOC in dry matter, 2% of N in dry substance, moisture - 60%.
g of CH_4/kg of waste		g of N_2O/kg of waste		
10 (0.08-20)	4 (0.03-8)	0.6 (0.2-1.6)	0.3 (0.06-0.6)	

7.3.3 Uncertainties and time-series consistency

Ranges of uncertainty indicators were calculated in accordance with 2006 IPCC Guidelines [1] and are presented in Table 7.13.

Table 7.13. Uncertainty ranges

Parameter	Designation	Default data	Range		Standard uncertainty	Estimated uncertainty	
			Bottom limit	Upper Limit		Bottom limit, -	Upper limit, -
Activity data							
Mass of composted waste	M				±100 %	30.56 %	30.56 %
Emission factors							
Methane	EF_{CH4}	4	0.03	8	±100 %	100	100
Nitrous oxide	EF_{N20}	0.3	0.06	0.6	±100 %	100	100
Standard uncertainty of emissions							
Methane						104.57	104.57
Nitrous oxide						104.57	104.57

7.3.4 Category-specific QA/QC procedures

Analysis of various sources of input data on waste composting in Ukraine was held, and work to increase reliability of source data by their processing and classification in accordance with [1] was conducted.

Together with the relevant experts of the State Statistics Service of Ukraine verification of activity data on waste composting was provided.

7.3.5 Category-specific recalculations

In this sub-category, no recalculations were held.

7.3.6 Category-specific planned improvements

In this category, no improvements are planned.

7.4 Incineration and Open Burning of Waste (CRF category 5.C)

7.4.1 Category description

CO_2, CH_4 and N_2O emission from incineration and open burning of waste is separated to biogenic and non-biogenic emission based on the fraction of fossil and biogenic carbon in the combusted waste material.

CO_2 emissions from combustion of biomass materials are biogenic emissions and are not included in national total emission estimates. CO_2 emissions from oxidation during incineration of carbon in fossil origin waste are considered net emissions and are reported under Waste sector. N_2O and CH_4 emissions include both biogenic and non-biogenic sources of emission.

CH_4, N_2O, and CO_2 emissions from combustion of waste are estimated in line with [1]:

- CH_4 and N_2O from waste incineration without energy recovery - under Tier 1;
- CO_2 (carbon of fossil origin) from waste incineration without energy recovery - Tier 1; for the exception of emissions from MSW combustion, where the methodological approach of Tier 2 was used for the calculations.

CO_2, CH_4, N_2O emissions from waste incineration without energy recovery in 1990-2021 is presented in Figure 7.8 and Table 7.14

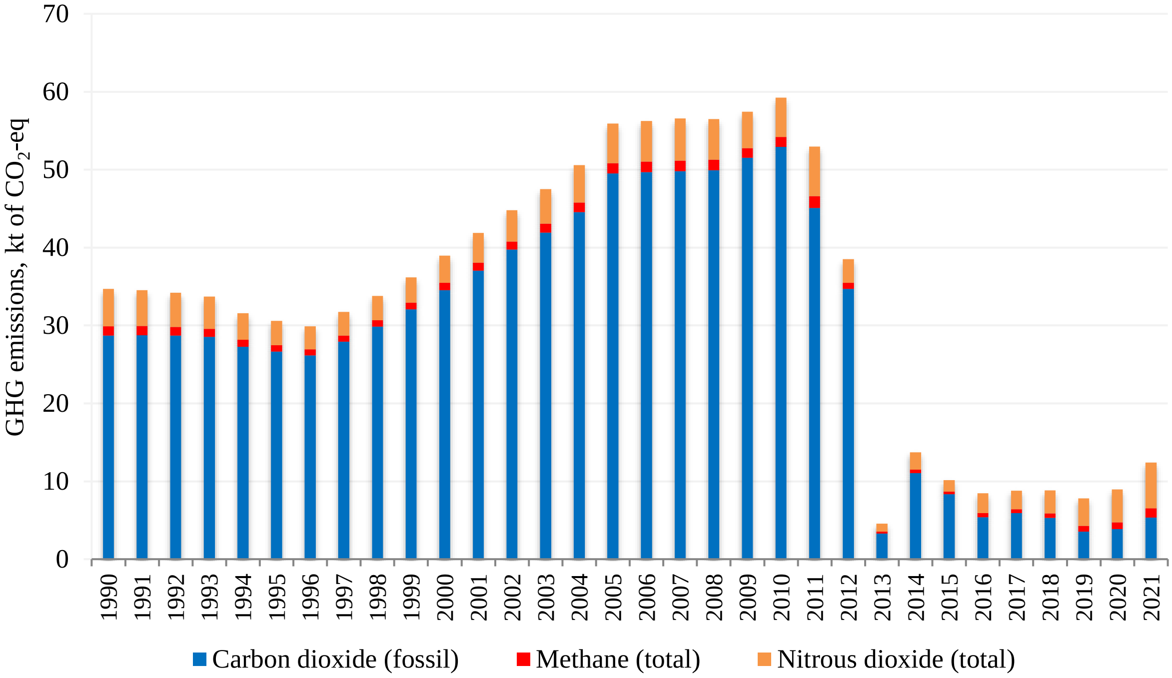


Fig. 7.8. GHG emissions from waste incineration without energy recovery in Ukraine, 1990-2021

Table 7.14. The amount of waste incinerated and GHG emissions from waste incineration in Ukraine, 1990-2021

	1990	2000	2005	2010	2012	2014	2015	2016	2017	2018	2019	2020	2021
Waste incinerated with energy recovery, kt (Energy sector)	952.2	550.7	903.8	840.3	1082.9	873.5	1086.2	1035.3	1008.5	951.2	960.1	905.1	936,16
Waste incinerated without energy recovery, kt (Waste sector), kt	201.2	156.4	221.1	218.1	133.0	74.9	49.8	67.2	60.0	87.9	112.6	123.6	111,5
CO_2 (fossil), kt CO_2	28.68	34.54	49.50	52.91	34.69	11.04	8.35	5.38	5.93	5.30	3.55	3.88	5.35
CO_2 (bio), kt CO_2	146.0	93.68	129.04	150.73	66.53	63.14	40.52	57.14	46.74	59.29	98.14	113.1	114.6

	1990	2000	2005	2010	2012	2014	2015	2016	2017	2018	2019	2020	2021
Total CH_4 (total), kt CH_4	0.048	0.037	0.052	0.052	0.031	0.018	0.012	0.020	0.019	0.023	0.028	0.034	0.047
Total N_2O (total), kt N_2O	0.016	0.012	0.017	0.017	0.010	0.007	0.005	0.009	0.008	0.009	0.012	0.014	0.020

GHG emissions from waste incineration without energy recovery in 2021 amounted to 12.38 kt of CO_2-eq., including: CH_4 – 0.047 kt (1.168 kt of CO_2-eq.), N_2O – 0.020 kt (5.86 kt of CO_2-eq.), CO_2 – 5.35 kt. From 1990 to 2021 the emissions decreased by 64.3 %.

Fig. 7.8 shows that from 1990-1996, GHG emissions in this category decreased by 1.2 times, which is due to a decrease in industrial production and MSW generation. From 1997 and to 2007, GHG emissions were steadily increasing and reached 56.56 kt of CO_2-eq. The key factor in the GHG emission trends in 1997-2005 is a sharp increase in plastic content of MSW (from 9.4% to 12.0%), which is the main source of CO_2 in the category. Besides, this period is characterized by a significant growth in industrial production and an increase in MSW. In 2005-2010, annual changes in GHG emissions were insignificant (there was a decline in industrial production, but an increase in MSW generation). Reduction of GHG emissions in 2011 was due to the closure of one of the two operating waste incineration plants (WIP) in Dnipropetrovsk at that time. The dramatic reduction of GHG emissions in 2013 was due to the fact that the only one operating WIP (Kyiv) was subject to reconstruction in that year. Nowadays incinerating waste without energy recovery facilities needs special authorization documents.

In Ukraine, thermal treatment of waste outside specially designated equipped areas is prohibited by law, so there is no official statistics on open burning of municipal waste by population. Thus, no emissions were estimated for the category "Open burning of waste" (CRF 5.C.2). Moreover, to prevent underestimation of the CO_2 emissions the regional authorities were officially questioned about the existing situation with MSW treatment in private sector, as well as the lead experts were interviewed.

In order to reveal the facts of unauthorized open burning of waste by the population expert meetings with relevant specialists from all regional administrations were held. According to the results of the expert meetings, single cases of open burning were uncovered only in the Vinnytsia and Chernihiv regions. To estimate the maximum possible amount of GHG emissions from the burning of waste by the population of Vinnytsia and Chernihiv regions an expert assessment was conducted.

The conservative assessment includes the following assumptions:

- MSW generation per person for the territory where there is no centralized waste collection is equal to those MSW that are generated on the territory covered by centralized collection;

- the volume of generated MSW in areas not covered by a centralized collection was burnt and it was not included in the official statistics on the treatment of solid waste in the country;

- the composition of the generated MSW in rural areas uncovered by centralized collection corresponds to the composition of solid waste in Ukraine.

The open burned MSW volumes were determined by the formula 5.7 of chapter 5 Guidelines, 2006 on the basis of available population data from the State Statistics Service for 2014 and the Ministry for Communities and Territories Development of Ukraine Official. Detailed data is provided in Table. 7.15. The volumes of theoretically possible MSW combustion were 68.5 kt.

Table 7.15. Waste management in the Vinnytsia and Chernihiv oblasts, 2014

Parameter	Vinnytsia	Chernihiv
Population, person	1618262	1066826
The amount of MSW collected, tons	216926	236501.2
The share of population covered by a centralized collection, %	83.7	90.0

Detailed information on the composition of the MSW and the amount of possible combustion is given in Table 7.16.

Table 7.16. Waste composition and waste amount which can be burnt in Vinnytsia and Chernihiv regions, 2014

Waste composition	Share, %	Possible burning waste, kt
Paper	13.7	9.4
Textiles	3.9	2.7
food waste	31.8	21.8
Wood	1.8	1.2
garden and park waste	3.6	2.5
personal care	1.4	0.9
rubber and leather	1.9	1.3
Plastic	12.9	8.9
Glass	12.2	8.4
ferrous metals	2.0	1.3
non-ferrous metals	0.4	0.3
hazardous waste	0.5	0.4
other organics	13.9	9.5

Volumes of maximum possible carbon combustion of fossil origin were defined as the amount of fossil carbon content in each component based on humidity, carbon content and fraction of fossil carbon in the MSW components in accordance with the IPCC Guidelines 2006 (Chapter 2, Table. 2.4). The volumes of maximum possible fossil carbon combustion from open burning of solid waste amounted to 7.33 kt.

The maximum possible CO_2 emissions can be determined by the amount of burnt fossil carbon. They amounted to 27.87 kt. According to the Guidelines, 2006, CH_4 specific emissions amounted to 6.500 g/ton of MSW, and N_2O – 0.15 g/kg of MSW in a dry condition. Thus, CH_4 emissions amounted to 0.445 kt, and N_2O emissions – 0.00758 kt. Total maximum possible GHG emissions from open burning of solid waste equals 40.27 kt of CO_2-eq.

Analysis of the collected information has shown that the theoretically possible maximum of CO_2 emissions from open burning is lower than 0.05 % of total GHG emissions in Ukraine, so the corresponding emissions are insignificant and reported as "NE" in the CRF tables.

Therefore, the category includes emissions from incineration of solid municipal, medical, and industrial waste at incinerators, as well as at stationary and mobile specialized sites. Emissions from thermal processes with energy recovery, in accordance with the Guidelines [1], are included in the "Energy" sector.

7.4.2 Methodological issues

7.4.2.1 General principles

Estimation of GHG emissions from waste incineration in the "Waste" sector is performed in accordance with the equations [1]:

$$Q_{CO_2} = MSW \cdot \sum_j (WF_j \cdot dm_j \cdot CF_j \cdot FCF_j \cdot OF_j) \cdot 44/12, \quad (7.9)$$

where: Q_{CO_2} is CO_2 emissions over the reporting year, kt/year;

MSW – the total amount of solid waste in the wet weight subject to incineration, tons/year;

WF_j – the proportion of the waste type/component of component *j* in MSW (in the wet weight, subject to incineration);

dm_j – dry matter content in component *j* in MSW subject to incineration;

CF_j – carbon fraction of dry matter of component *j*;

FCF_j – the share of fossil carbon in the total amount of component *j*;

44/12 – the conversion factor from C to CO_2;

j – MSW components subject to incineration, such as paper/cardboard, textiles, food waste, garden and park waste, plastic, etc.

$$Q_{CH_4} = MSW \cdot \sum_i (IW_i \cdot EF_i) \cdot 10^{-6}, \quad (7.10)$$

where: Q_{CH_4} is CH_4 emissions over the reporting year, kt/year;

IW_j – amount of solid waste of type i (wet matter) subject to incineration or open burning, kt;

EF_j – CH_4 emission component factor, kg of CH_4/kt of waste;

10^{-6} – conversion factor kg to kt;

i – waste category subject to incineration; MSW - municipal solid waste, CW – clinical waste, SS – sewage sludge, other (if relevant, specified).

Emissions of N_2O can be estimated using equation (7.11), similarly to equation (7.10):

$$Q_{N_2O} = MSW \cdot \sum_i (IW_i \cdot EF_i) \cdot 10^{-6}, \quad (7.11)$$

where: Q_{N_2O} is N_2O emissions over the reporting year, kt/year.

7.4.2.2 Activity data

Since 2015, accounting of waste incineration volumes in Ukraine has been conducted in accordance with two reporting forms:

- "No.1 – TPV" (Ministry of Communities and Territories Development of Ukraine).
- "No.1 – waste" (State Statistics Service of Ukraine).

Form "No.1 – waste" includes information on all the waste that is incinerated in Ukraine, data on the type of waste are submitted directly from the enterprises. Form "No.1 – TPV" includes information about MSW incineration, which fully and in greater detail are also shown in "No.1 – waste". Therefore, a more reliable source of data on the weight and type of incinerated waste at the level of enterprises is form "No.1 – waste".

Data collection by the State Statistics Service of Ukraine in accordance with form "No.1 – waste" is held annually since 2010. According to data of the SSSU, data on incineration of waste without energy generation are presented in Table 7.17.

For the necessary and sufficient aggregation of waste categories for the period of 1990-2015 (based on the characteristics of GHG inventory), the entire set of primary source data was analyzed and processed, as well as the analytical study [39] and the method of restoring the missing time series data for 1990-2009 was proposed.

At *stage I*, data were grouped into 3 categories and 7 subcategories: municipal solid and similar waste (I), industrial waste (II) (disaggregated by sub-categories: paper and cardboard (IIa), rubber (IIb), plastic (IIc), wood (IId), textiles (IIe), plant and animal residues (IIf) and other (IIg)), as well as clinical waste (III).

Table 7.17. Waste incineration without energy generation in Ukraine in 2010-2021, tons

Component*	Year								
	2010	2012	2014**	2015**	2016**	2018**	2019**	2020**	2021**
Solvents used	0.3	0.3	8.6	38.8	64.5	571.5	885.1	1103.9	1040.0[1]
Waste of acids, alkali, and salts	5435.4	7159.5	4915.8	2072.8	4167.2	4732.7	5350.3	3675.2	3545.1[1]
Waste oils	325.9	477.0	152.2	3152.5	3164.9	762.6	1695.5	2320.9	1199.4
Chemical waste	28906.2	20563.6	2196.7	349.7	385.9	1909.0	1198.8	1295.2	1342.8[1]
Sludge of industrial effluents	52.9	12.7	331.3	1022.1	2326.9	1068.0	170.6	860.7	0.0
Medical care and biological waste	405.6	265.6	500.0	445.0	1135.9	1105.1	863.4	1409.9	2975.7
Metal scrap	4.2	0.0	18.5	0	0.0	131.6	97.5	134.5	146.3[1]
Glass waste	1.7	0.0	1.3	2.0	1.5	42.1	38.2	33.3	36.8[1]

Component*	Year								
	2010	2012	2014**	2015**	2016**	2018**	2019**	2020**	2021**
Paper and cardboard waste	463.1	69.0	143.6	105.2	199.7	590.4	279.7	278.9	276.0
Rubber waste	20.1	114.4	53.2	27.7	74.7	173.3	16.5	64.0	67.2[1]
Plastic waste	172.2	11.6	2708.2	2110.0	520.2	369.8	327.5	292.5	205.6
Wood waste	49847.1	10888.3	27880.9	17887.2	17701.3	18697.6	41213.5	49864.1	58566.9[1]
Textile waste	192.7	108.9	81.1	30.7	176.7	1245.2	105.3	109.6	99.7
Plant and animal residues	5090.3	11593.7	29497.8	19002.0	34970.4	46964.8	56720.1	58635.3	34334.7
Wastes that contains polychlorinated biphenyls	103.0	10.2	0.0	0.0	0.0	95.4	90.8	0.0	0.0
Nonfunctional equipment	86.7	78.2	9.3	8.8	17.8	14.2	30.0	96.9	1348.6
Household and similar waste	126119.2	78565.5	3746.8	2110.3	2010.2	978.2	998.3	710.1	921.1[1]
Mixed and undifferentiated materials	294.3	1802.0	2267.9	1149.6	563.8	5387.7	2029.3	1745.1	1461.2[1]
Sorting residues	31.4	378.7	0.0	0	0.0	0.0	0.0	0.0	0.0
Sludge of domestic wastewater	214.8	8.0	0.0	3.0	0.0	0.1	8.8	0.0	0.0
Waste rock from bottom reinforcement work	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
Mineral waste	279.6	892.7	241.4	231.4	145.5	924.8	109.7	97.2	399.5
Hardened, stabilized or glassy waste	45.5	37.9	186.1	10.6	43.5	2184.5	351.4	868.6	3578.5
Total	**218092.2**	**133037.8**	**74932.7**	**49759.4**	**67215.7**	**87853.1**	**112579.1**	**123595.4**	**111545.2**

*List of wastes by materials according to the order 23.01.2015 №24
**Data of the State Statistic Service of Ukraine, corrected using analytical study [36]
[1] data extrapolated

Results of *stage I* of raw data processing are shown in Table 7.18.

Table 7.18. MSW incineration without energy generation in Ukraine in line with the suggested waste classification, tons, 2010-2021

Component	Designation	Year								
		2010	2012	2014*	2015*	2016*	2018*	2019*	2020*	2021*
Municipal solid and similar waste	I	126119.2	78565.5	3746.8	2110.3	2010.2	978.2	998.3	710.1	921.1
Industrial	II	91567.4	54206.7	70685.9	47204.0	64069.5	85865.3	110717.4	121475.1	107648.4
paper and cardboard	a	463.1	69.0	143.4	105.2	199.7	590.4	279.7	278.9	276.0
Rubber	b	20.1	114.4	53.1	27.7	74.7	173.3	16.5	64.0	67.2
Plastic	c	172.2	11.6	2704.4	2110.0	520.2	369.8	327.5	292.5	205.6
Wood	d	49847.1	10888.3	27880.9	17887.2	17701.3	18697.6	41213.5	49864.1	58566.9
Textile	e	192.7	108.9	81.2	30.7	176.7	1245.2	105.3	109.6	99.7
plant and animal residues	f	5090.3	11593.7	29497.8	19002,0	34970.4	46964.8	56720.1	58635.3	34334.7
Other	g	35781.9	31420.8	10325.1	8041.1	10426.6	17824.2	12054.9	12231.1	14168.4
Clinical waste	III	405.6	265.6	500.0	445.0	1135.9	1105.1	863.4	1409.9	2975.7

*Data of the State Statistic Service of Ukraine, corrected using analytical study [36]

Based on results of *stage II*, the time series for waste incineration with/without generation(s) of energy in Ukraine for the categories for the period of 1990-2009 was restored.

When assessing data for all categories of waste, the following assumptions were proposed:

- The change in the weight of incinerated Category I for the period of 1990-2009 depends on MSW generation and dumping.
- The change in the weight of incinerated Category II for the period of 1990-2009 depends on the industrial production index.
- The change in the weight of incinerated Category III for the period of 1990-2009 depends on the country's population.
- The structure of the incinerated Category II for the period of 1990-2009 is a constant.
- To restore the 1990-2009 time series the average value of incinerated waste for 2010-2013 was multiplied by each of the above indicators.

Estimation of the weight of waste incinerated without electricity production in Ukraine for the period of 1990-2009 is shown in Table 7.19.

Table 7.19. Waste incineration without energy generation in Ukraine in 1990-2009

Year	Waste category Tons										MSW dumping kt	Plastic content of MSW, % of wet weight	Industrial production index, % to the previous year
	I	II:	a	b	c	D	e	f	g	III			
1990	99886.0	101114.7	302.3	124.0	126.1	34136.0	147.7	20356.5	45922.2	224.5	9872.9	6.9	99.9
1991	97476.7	96261.2	287.8	118.0	120.0	32497.4	140.6	19379.4	43717.9	224.9	9634.7	7.2	95.2
1992	95018.6	90100.5	269.4	110.5	112.3	30417.6	131.6	18139.1	40920.0	225.4	9391.8	7.6	93.6
1993	92425.9	82892.4	247.8	101.6	103.3	27984.2	121.1	16688.0	37646.4	226.2	9135.5	8.0	92.0
1994	89187.5	60262.8	180.2	73.9	75.1	20344.5	88.0	12132.1	27368.9	225.7	8815.4	8.4	72.7
1995	85446.3	53031.3	158.6	65.0	66.1	17903.2	77.5	10676.3	24084.6	224.0	8445.6	8.7	88.0
1996	81591.9	50326.7	150.5	61.7	62.7	16990.1	73.5	10131.8	22856.3	222.1	8064.7	9.1	94.9
1997	85723.5	50175.7	150.0	61.5	62.6	16939.1	73.3	10101.4	22787.8	220.0	8473.0	9.4	99.7
1998	89852.5	49673.9	148.5	60.9	61.9	16769.7	72.6	10000.4	22559.9	218.1	8881.1	9.7	99.0
1999	93863.3	51660.9	154.5	63.3	64.4	17440.5	75.5	10400.4	23462.3	216.2	9277.6	10.1	104.0
2000	97722.0	58480.1	174.8	71.7	72.9	19742.7	85.4	11773.3	26559.3	214.0	9659.0	10.5	113.2
2001	101402.5	66784.3	199.7	81.9	83.3	22546.1	97.6	13445.1	30330.7	211.8	10022.8	10.8	114.2
2002	105000.8	71459.2	213.7	87.6	89.1	24124.4	104.4	14386.2	32453.9	209.8	10378.4	11.3	107.0
2003	108931.3	82749.8	247.4	101.5	103.2	27936.0	120.9	16659.2	37581.6	207.9	10766.9	11.3	115.8
2004	113015.0	93093.5	278.3	114.1	116.1	31428.0	136.0	18741.6	42279.3	206.2	11170.6	11.5	112.5
2005	124868.4	95979.4	287.0	117.7	119.7	32402.3	140.2	19322.6	43589.9	204.7	12342.2	11.7	103.1
2006	122362.0	101930.1	304.8	125.0	127.1	34411.2	148.9	20520.6	46292.5	203.2	12094.4	11.9	106.2
2007	119855.7	109167.2	326.4	133.9	136.1	36854.4	159.5	21977.6	49579.3	202.0	11846.7	12.0	107.1
2008	119722.5	103708.8	310.1	127.2	129.3	35011.7	151.5	20878.7	47100.3	200.8	11833.5	12.1	95.0
2009	124935.3	82344.8	246.2	101.0	102.7	27799.3	120.3	16577.7	37397.6	199.8	12348.8	12.3	79.4

7.4.2.3 Selection of emission factors

Only one waste incineration plant (Energia Incineration Plant) operates in Ukraine in Kyiv. Type of furnace is a rotary stoker furnace and the plant was constructed by CKD Dukla, a Czech company with a licensing agreement with a company in Dusseldorf in Germany. However, the incineration plant "Energia" is produces heat for district supply purposes. Thus, this process is considered as a recovery operation because of the production of heat used by two residential districts of Kyiv City. And the emissions from incineration with energy recovery are reported in the Energy Sector.

According to State Statistics Service, about 105 kt of industrial waste were incinerated without energy recovery (as a disposal operation) by 105 incinerators (42 enterprises) in 2020. There is currently no information on the types and technologies incineration of waste incinerators. The State Statistics Service provides only data on the capacity of incinerators. Due to the low capacity of incinerators, the batch type incineration was used to select the emission factor. Thus, the values for methane emissions factor for all types of waste (MSW, industrial and clinical) were accepted to be 237 kg/Gg waste incinerated on a wet weight basis (according to table 5.3, section 5.4.2, vol. 5, chapter 5 [1]); for nitrogen oxide emissions factor – 60 g N_2O/t waste for the type of MSW and 100 g N_2O/t waste for the type of industrial and clinical waste (according to table 5.6, section 5.4.3, vol. 5, chapter 5 [1]).

The values of dry matter content in the component *j*, fraction of carbon in the dry matter, fraction of fossil carbon in the total carbon of component *j* were taken by default in Section 5.2.3, table 2.4 of 2006 IPCC Guidelines (vol. 5) (see Table 7.20). The composition of MSW in Ukraine and fraction of component *j* in the MSW is presented in Section 7.2.

Table 7.20. Default dry matter content, total carbon content and fossil carbon fraction of different MSW components

MSW component	**Municipal solid and similar waste I**											
	paper and paper board	*textile*	*food*	*wood*	*garden and park*	*personal care products*	*rubber and leather*	*plastics*	*glass*	*metal*	*hazardous*	*other non-organ*
Dry matter content	90	80	40	85	40	40	84	100	100	100	90	90
Fraction of carbon in the dry matter	46	50	38	50	49	70	67	75	0	0	3	3
Fraction of fossil carbon in the total carbon	1	20	0	0	0	10	20	100	0	0	100	100

DOC and fossil carbon content in industrial waste for the components were taken by default in Section 5.2.3, Table 2.5 of 2006 IPCC Guidelines (vol. 5) and for the clinical waste – from Table 2.6 of 2006 IPCC Guidelines (vol. 5) (see Table 7.21).

Table 7.21. Default DOC and fossil carbon content in industrial and clinical waste

	Industrial waste II							**Clinical waste III**
	a	b	c	d	e	f	g	
DOC	40	39	0	43	24	15	1	15
Fossil carbon	1	17	80	0	16	0	3	25
Total carbon	41	56	80	43	40	15	4	40

7.4.3 Uncertainties and time-series consistency

Uncertainty ranges were estimated in accordance with [1] and presented in Table 7.22.

Table 7.22. Uncertainty estimation ranges

	Estimated uncertainty	
	"-"	"+"
Activity data		
Mass of incinerated	30	30
Emission factors		
Waste composition	10	10
Dry matter content in waste	10	10
Share of fossil carbon	15	15
Oxidation factor	5	5
Carbon fraction in dry matter	15	15
Uncertainty of CH_4 emission factors	100	100
Uncertainty of N_2O emission factors	100	100
Standard uncertainty of CO_2 emissions	**40.5**	**40.5**
Standard uncertainty of N_2O emissions	**104.7**	**104.7**
Standard uncertainty of CH_4 emissions	**104.7**	**104.7**

7.4.4 Category-specific QA/QC procedures

Analysis of various sources of input data on waste incineration in Ukraine was held, and work to increase reliability of source data by their processing and classification in accordance with [1] was conducted.

7.4.5 Category-specific recalculations

In this sub-category, recalculations were carried out due to the correction of the amount of incinerated clinical waste in 2020. Results of recalculation are provided in Table 7.23.

Table 7.23. Recalculation in subcategory 5.C.1 "Waste incineration"

Year	Inventory Report, 2022 submission, kt			Inventory Report, 2023 submission, kt			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
2020	3.8886	0.03366	0.01417	3.8813	0.03361	0.01415	-0.188	-0.158	-0.158

7.4.6 Category-specific planned improvements

In this category, no improvements are planned.

7.5 Wastewater Treatment and Discharge (CRF category 5.D)

7.5.1 Category description

This category accounts for GHG emissions from the following emission sources:

- Treatment and discharge of domestic sewage – for methane under Tier 2 applying national and default factors, for nitrous oxide emissions – under Tier 1 with default factors.
- Industrial sewage treatment and discharge – under Tier 2.

In 2021 GHG emissions in this category amounted to 4 430.97 kt CO_2-eq (36.44 % of total GHG emissions in the "Waste" sector), having decreased compared to 1990 (5 842.64 kt CO_2-eq) by 24.2 % and increase by 4.63 % compared to 2020.

GHG emissions from treatment of industrial sewage amounted to 1 207.33 kt CO_2-eq (27.2 % of the category), of methane from domestic sewage – 2 231.91 kt of CO_2-eq (50.4 % of the category), and of nitrous oxide from human life activity sewage – 991.73 kt CO_2-eq (22.4 % of the category). Dynamics of GHG emissions at wastewater treatment is presented in Fig. 7.9.

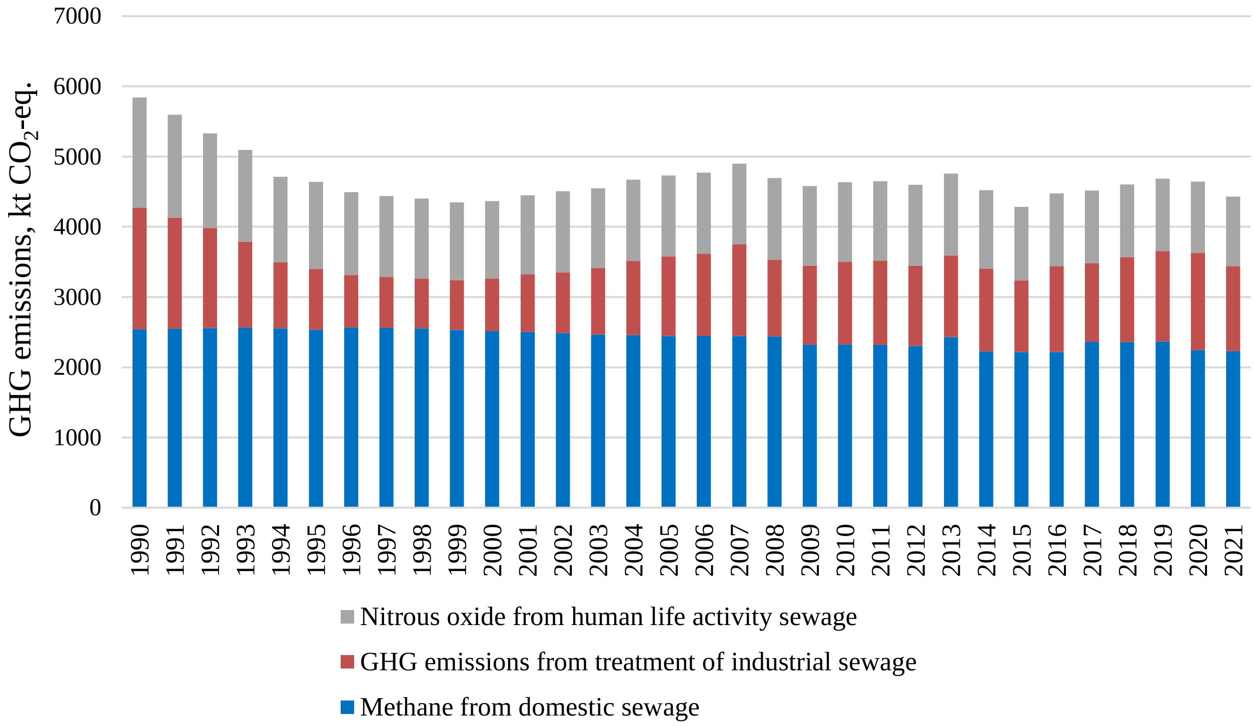


Fig. 7.9. Greenhouse gas emissions from waste water treatment in Ukraine, 1990-2021

7.5.2 Methane emissions from domestic wastewater treatment (CRF sub-category 5.D.1.1)

7.5.2.1 Category description

Methane emissions from treatment of domestic sewage amounted to 2 231.91 kt CO_2-eq (89.27 kt CH_4) in 2021. The reduction in emissions relative to 1990 (2 540.62 kt CO_2-eq) constituted 12.15 %, compared to 2020 – decreasing by 0.6 % (Fig. 7.10).

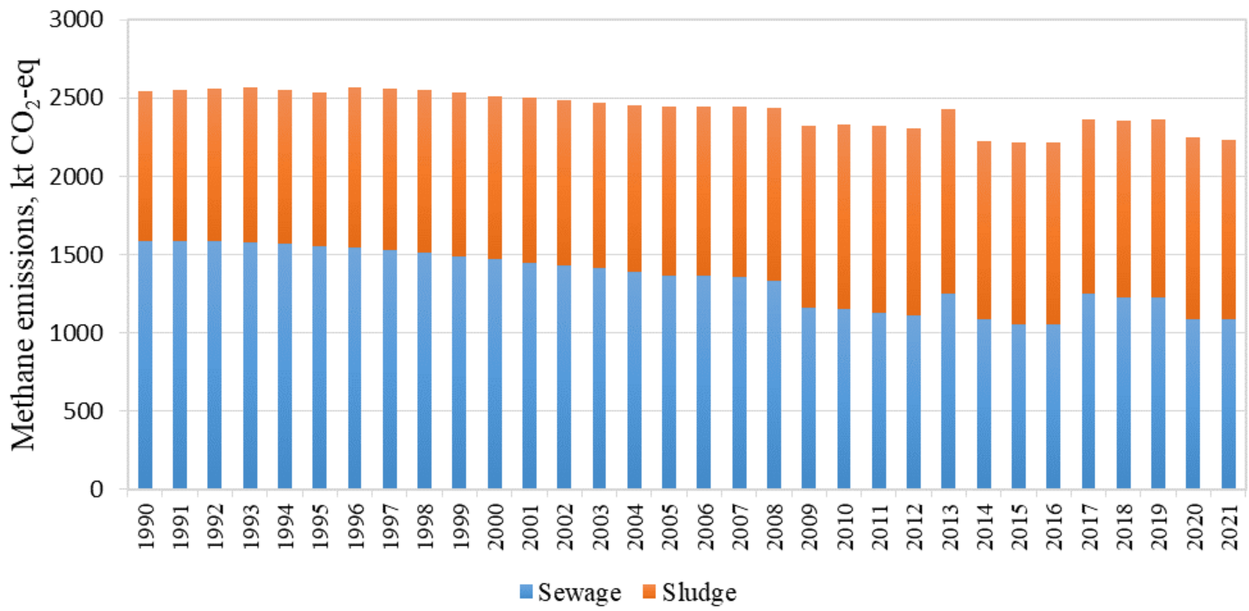


Fig. 7.10. Methane emissions from domestic sewage and sludge treatment in Ukraine, 1990-2021

Gradual reduction of GHG emissions from 1990 to 2021 is mainly due to decrease on population of Ukraine. The fluctuation of methane emissions in this sub-category from 2009 to 2021 is associated with a change in the amount of *insufficiently treated water*.

Structure of domestic wastewater drainage system in Ukraine is presented in the Figure 7.11.

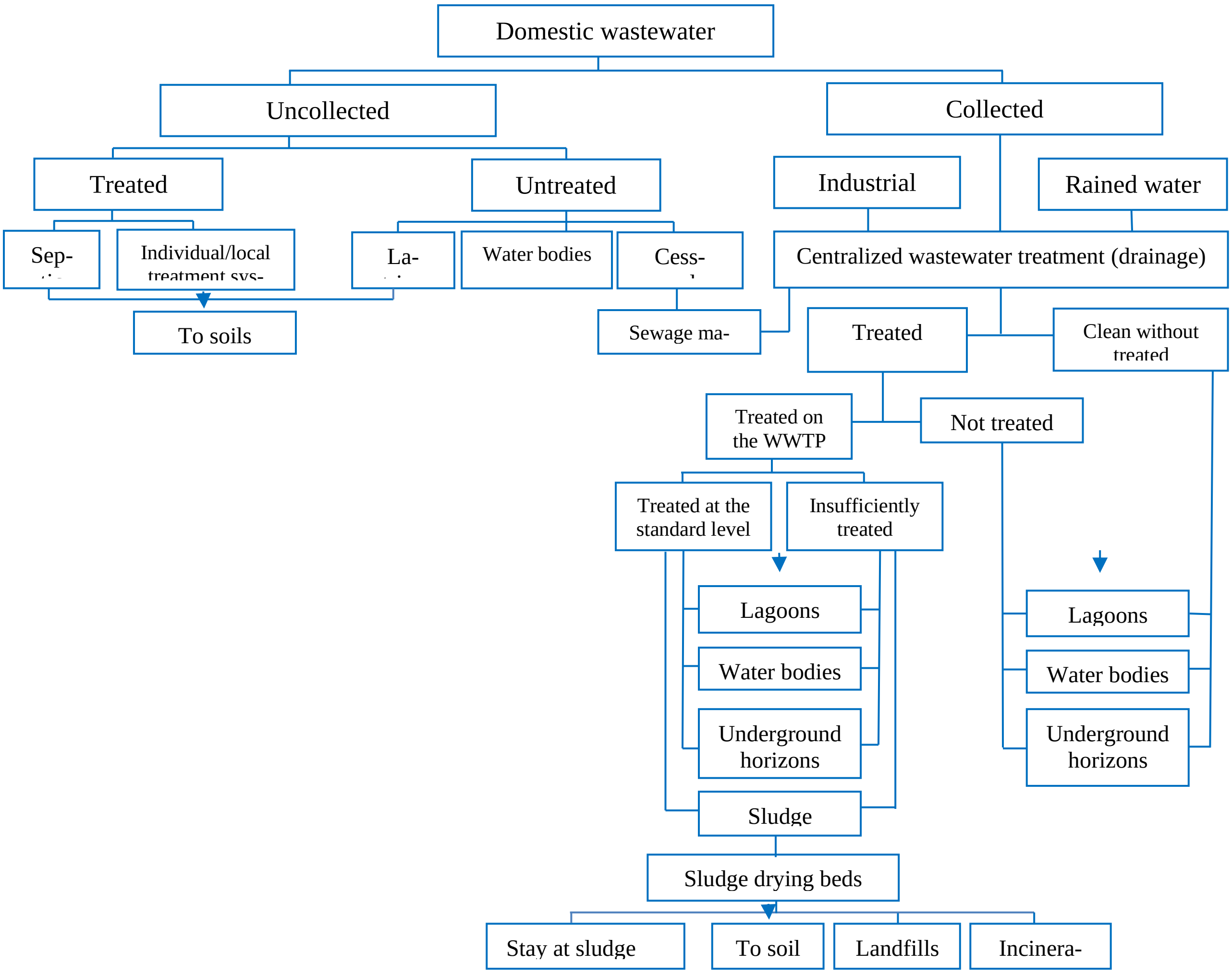


Fig. 7.11. Structure of domestic wastewater drainage system in Ukraine

7.5.2.2 Methodological issues

7.5.2.2.1 General principles

Estimation of methane emissions from domestic wastewater treatment was executed in line with the procedure set out in the research work "Research in methane and nitrous oxide emissions from waste water treatment and development of methods to determine national emission factors" [30].

Methane emissions from domestic wastewater treatment were determined under formula [30].

$$E_{CH4} = 365 \times \sum_k P \times q_{BOD} \times F_k \times B_0, \quad (7.12)$$

where P – population, persons;
$q_{BOD} = 50$ – generation of BOD_5 per capita daily, g/pers./day;
F_k – biodegrable part of BOD that produce methane for different BOD flows (tabl. 7.26);
$B_0 = 0.6$ – maximum methane production capacity, kg of CH_4/kg of BOD [1].

7.5.2.2.2 Activity data

Generalization of data on the use of water in Ukraine is done by the State Water Agency of Ukraine and reflected in statistical reporting form No. 2-TP (water management). Structure of the statistical form No. 2-TP on discharges of return water include: the list of industries; volumes of wastewater treated by different types of treatment (mechanical, biological, physico-chemical) at central WWTP and then discharged into water bodies (surface and underground), irrigation fields or other systems; the volume of wastewater discharged by treatment category: not treated water; insufficiently treated water; water treated at the standard level.

Classification of treated wastewater into "*not treated*", "*insufficiently treated*" and "*treated at the standard level*" is based on a comparison of the actual quantity of discharged pollutants and maximum permissible concentration/norms:

- *contaminated wastewater:* ***not treated*** *water and* ***insufficiently treated*** *water.* Such water contains various pollutants and it is discharged into natural water bodies or other systems without treatment or the degree of their treatment does not correspond to maximum permissible concentration/norms;

- *wastewater* ***normatively clean without being treated***. Discharging such waters into water bodies does not lead to deterioration of water quality standards.

- *wastewater* ***treated at the standard level*** *at the treatment plants in biological, physico-chemical and mechanical ways.* Discharging such waters after treatment into water bodies does not lead to deterioration of water quality standards.

Domestic wastewater in Ukraine is mainly treated by two ways: collected/centralized treatment systems (aerobic wastewater treatment plants) and not collected/decentralized (septic tanks, cesspools, latrines). Urban wastewater is largely treated in the first way, rural wastewater – mainly in the second one. The degree of application of domestic sewage treatment and discharge systems in Ukraine is presented in the Table 7.24.

Aeration stations operate according to the classical scheme of sewage treatment, developed in the Soviet Union and used almost in all countries of the former Soviet Union. It includes mechanical (screens, sandblasters and radial primary sedimentation tanks) and biological treatment (aeration tanks and secondary sedimentation tanks). Methods of biological treatment of wastewater from nitrogen and phosphorus compounds are not common practice in Ukraine.

Sewage sludge is recyclable to reduce its volume and disinfect it. Sludge treatment is done in special facilities – methane tanks and aerobic stabilizers. Anaerobic sludge digestion in methane tanks is practiced in Ukraine only at Bortnychi Sewage Treatment Plant. Then, sludge is pumped to the sludge-drying beds for further drying under natural or artificial conditions.

Due to the absence of any technologies for the efficient utilization of sludge (they were not foreseen by the projects in the 1950s), the sludge fields/sludge-drying beds are the only way to their processing, dewatering and utilization. More detailed information on sludge-drying beds is presented in section 7.5.2.2.3.

The population and the proportion of population having access to sewerage were determined based on data of the State Statistics Service of Ukraine. The degree of application of sewage treatment or discharge systems (see Table 7.24) was determined based on data of the State Water Agency of Ukraine reflected in statistical form No. 2-TP (water management).

Generation of BOD_5 per capita daily was taken as 50 g/pers./day as the national factor on the basis of [30] with regard to the current state sanitary regulations [31]. BOD flows are presented in Table 7.25.

Table 7.24. The degree of application of domestic sewage treatment and discharge systems in Ukraine, 1990-2021

Year	Collected domestic waste water, %								Latrines, %
	Total	Centralized systems				Decentralized systems			
		Total	Treated at the standard level	Insufficiently treated	Not treated	Total	Septic tanks	Cesspools	
1990	45.72	34.06	8.24	22.60	3.22	11.66	0.11	11.55	54.28
1991	45.94	34.22	8.51	22.53	3.18	11.72	0.12	11.60	54.06
1992	46.18	34.40	8.80	22.47	3.14	11.78	0.13	11.65	53.82
1993	46.47	34.62	9.11	22.41	3.09	11.85	0.14	11.71	53.53
1994	46.61	34.72	9.41	22.27	3.04	11.89	0.16	11.73	53.39
1995	46.79	34.85	9.74	22.14	2.98	11.93	0.17	11.76	53.21
1996	49.08	36.56	10.25	23.23	3.08	12.52	0.21	12.31	50.92
1997	49.94	37.20	10.72	23.42	3.06	12.74	0.23	12.51	50.06
1998	50.57	37.67	11.17	23.49	3.01	12.90	0.24	12.66	49.43
1999	50.89	37.91	11.57	23.39	2.94	12.98	0.26	12.72	49.11
2000	51.25	38.18	12.02	23.29	2.86	13.07	0.28	12.80	48.75
2001	52.11	38.82	12.62	23.40	2.81	13.29	0.31	12.99	47.89
2002	52.65	39.22	13.18	23.32	2.72	13.43	0.34	13.09	47.35
2003	52.85	39.37	13.70	23.07	2.61	13.48	0.37	13.11	47.15
2004	53.39	39.77	14.34	22.93	2.50	13.62	0.40	13.22	46.61
2005	54.32	40.47	15.62	22.38	2.46	13.86	0.47	13.39	45.68
2006	54.55	40.63	15.90	22.68	2.04	13.91	0.65	13.26	45.45
2007	55.28	41.18	16.40	22.60	2.18	14.10	0.82	13.28	44.72
2008	56.23	41.89	18.52	21.48	1.90	14.34	1.19	13.15	43.77
2009	57.29	42.68	27.54	13.49	1.65	14.61	1.63	12.99	42.71
2010	58.08	43.26	28.85	12.95	1.46	14.81	2.01	12.80	41.92
2011	58.85	43.84	30.86	11.69	1.29	15.01	2.34	12.67	41.15
2012	59.74	44.51	32.52	10.27	1.71	15.24	2.62	12.61	40.26
2013	60.17	44.82	26.84	16.78	1.19	15.35	2.84	12.51	39.83
2014	57.20	42.61	33.27	8.38	0.96	14.59	2.94	11.65	42.80
2015	58.80	43.80	35.01	7.19	1.61	15.00	3.14	11.86	41.20
2016	59.20	44.10	35.56	7.06	1.48	15.10	3.24	11.86	40.80
2017	58.90	43.88	25.79	16.62	1.47	15.02	3.18	11.85	41.10
2018	60.00	44.70	27.01	16.13	1.55	15.30	3.19	12.11	40.00
2019	60.56	45.11	27.32	16.59	1.19	15.45	3.23	12.22	39.44
2020	60.77	45.27	33.17	10.18	1.92	15.50	3.25	12.25	39.23
2021	60.22	44.86	32.73	10.63	1.50	15.36	3.23	12.13	39.78

Table 7.25. Amount of BOD_5 in domestic waste water treated in any way in Ukraine, 1990-2021

	Flows of BOD from DWW, kt of BOD_5/day								Latrines, kt of BOD_5/day	Total, kt of BOD_5/day
	Total	Centralized systems				Decentralized systems				
		Total	Treated at the standard level	Insufficiently treated	Not treated	Total	Septic tanks	Cesspools		
1990	1.1863	0.8837	0.2139	0.5864	0.0835	0.3026	0.0029	0.2997	1.4083	2.5946
1991	1.1944	0.8897	0.2213	0.5858	0.0826	0.3046	0.0030	0.3016	1.4057	2.6000
1992	1.2042	0.8971	0.2295	0.5859	0.0818	0.3072	0.0033	0.3038	1.4033	2.6075
1993	1.2124	0.9032	0.2378	0.5847	0.0807	0.3092	0.0038	0.3055	1.3965	2.6090
1994	1.2101	0.9014	0.2444	0.5782	0.0788	0.3086	0.0041	0.3045	1.3860	2.5961
1995	1.2050	0.8977	0.2508	0.5702	0.0767	0.3074	0.0045	0.3029	1.3706	2.5756
1996	1.2528	0.9333	0.2615	0.5931	0.0786	0.3195	0.0054	0.3142	1.3000	2.5529
1997	1.2633	0.9411	0.2711	0.5926	0.0773	0.3222	0.0057	0.3165	1.2665	2.5297
1998	1.2680	0.9446	0.2800	0.5891	0.0755	0.3234	0.0061	0.3174	1.2392	2.5072
1999	1.2640	0.9416	0.2875	0.5810	0.0730	0.3224	0.0064	0.3160	1.2197	2.4837
2000	1.2602	0.9388	0.2956	0.5727	0.0704	0.3214	0.0068	0.3146	1.1987	2.4588
2001	1.2680	0.9446	0.3071	0.5693	0.0683	0.3234	0.0075	0.3160	1.1652	2.4331
2002	1.2690	0.9454	0.3177	0.5621	0.0656	0.3237	0.0081	0.3156	1.1411	2.4101
2003	1.2635	0.9412	0.3275	0.5515	0.0624	0.3223	0.0088	0.3135	1.1272	2.3906
2004	1.2666	0.9435	0.3403	0.5439	0.0593	0.3231	0.0095	0.3135	1.1060	2.3726
2005	1.2795	0.9531	0.3679	0.5272	0.0580	0.3263	0.0110	0.3153	1.0758	2.3553
2006	1.2761	0.9506	0.3720	0.5307	0.0477	0.3255	0.0152	0.3103	1.0633	2.3394
2007	1.2856	0.9577	0.3814	0.5256	0.0507	0.3279	0.0190	0.3089	1.0399	2.3255
2008	1.3005	0.9688	0.4284	0.4968	0.0439	0.3317	0.0275	0.3042	1.0124	2.3129
2009	1.3193	0.9828	0.6341	0.3106	0.0379	0.3365	0.0374	0.2991	0.9834	2.3027
2010	1.3320	0.9923	0.6616	0.2971	0.0335	0.3397	0.0461	0.2936	0.9615	2.2935
2011	1.3448	1.0018	0.7052	0.2671	0.0294	0.3430	0.0534	0.2896	0.9405	2.2853
2012	1.3620	1.0146	0.7413	0.2340	0.0389	0.3474	0.0598	0.2876	0.9177	2.2797
2013	1.3684	1.0194	0.6104	0.3817	0.0270	0.3490	0.0645	0.2845	0.9060	2.2745
2014	1.2862	0.9582	0.7482	0.1885	0.0216	0.3281	0.0661	0.2619	0.9624	2.2486
2015	1.3174	0.9814	0.7844	0.1611	0.0361	0.3360	0.0704	0.2656	0.9231	2.2405
2016	1.3220	0.9848	0.7940	0.1577	0.0331	0.3372	0.0724	0.2648	0.9111	2.2331
2017	1.3100	0.9759	0.5736	0.3696	0.0327	0.3341	0.0706	0.2635	0.9141	2.2242
2018	1.3281	0.9894	0.5979	0.3571	0.0343	0.3388	0.0707	0.2680	0.8854	2.2136
2019	1.3333	0.9932	0.6016	0.3654	0.0261	0.3401	0.0712	0.2690	0.8684	2.2018
2020	1.3325	0.9926	0.7272	0.2232	0.0422	0.3399	0.0712	0.2687	0.8603	2.1928
2021	1.3100	0.9758	0.7120	0.2313	0.0326	0.3342	0.0704	0.2638	0.8654	2.1754

7.5.2.2.3 Selection of emission factors

The maximum methane production capacity by default was taken to be 0.6 kg of CH_4/kg of BOD [1].

Methane conversion rates, *MCF*, for different type of domestic wastewater treatment are defined in accordance with [1, 30] and presented in Table 7.26. According to the research [30], it's assumed that all aeration stations are well-managed and non-overloaded, taking into account the general statistics on incomplete utilization of the capacity of the treatment facilities in Ukraine. Therefore, the MCF value is 0 for the share of domestic wastewater, which is treated at the standard level. The MCF value is 0.2 for the part of the domestic wastewater classified as insufficiently treated. Insufficient treating is mainly due to the excess of the maximum permissible discharge of pollutants from treatment plants by the content of ammonium nitrogen, nitrites, nitrates and phosphates. In fact, the biological treatment facilities were designed over 60 years ago and designed to remove mainly organic pollution from wastewater by their technological purpose. Removing nitrogen and phosphorus compounds was not required in the process calculations. However, according to the results of the treatment facilities (WWTP) questioning the cases of BOD and COD indicators permissible limits exceeding has been established. 11 respondents of 64 indicated excesses on BOD and COD indicators. However, in the overall volume of treated wastewater the volume of water with exceeded of BOD and COD indicators is nearly 3 %. Thus, it was decided to accept the lower range (0.2) of the proposed coefficient by default.

In order to estimate methane emissions from wastewater discharge into open reservoirs (seas, rivers, lakes) the MCF value was taken by default 0.1 according to 2006 IPCC Guidelines (vol. 5, chapter 6, table 6.3). In order to account methane emissions from septic system the MCF value was taken by default 0.5 according to 2006 IPCC Guidelines (vol. 5, chapter 6, table 6.3). In the absence of reliable data on the types of latrines in Ukraine the MCF value was taken by default 0.1 according to 2006 IPCC Guidelines (vol. 5, chapter 6, table 6.3).

When estimating *BOD* flows, the efficiency E_{BOD} of their removal while was considered in accordance with [32]. The conversion factor MCF and biodegradable part of BOD for each types/methods of domestic sewage treatment see in Table 7.26.

Biodegradable parts ($F_{k,ww}$) of sewage BOD of different BOD flows were calculated based on the formulas [30]:

$$F_{tr} = E_{BOD.tr} \times MCF_{tr} + (100 - E_{BOD.tr}) \times MCF_w, \quad (7.13)$$
$$F_{ins.tr} = E_{BOD.ins.tr} \times MCF_{ins.tr} + (100 - E_{BOD.ins.tr}) \times MCF_w, \quad (7.14)$$
$$F_{not.tr} = MCF_w, \quad (7.15)$$
$$F_{sept} = MCF_{sept}, \quad (7.16)$$
$$F_{cessp} = (F_{tr} + F_{ins.tr})/2, \quad (7.17)$$
$$F_{latr} = MCF_{latr}, \quad (7.18)$$

where $E_{BOD.tr} = 0.9164$ – efficiency of BOD removal for treated wastewater [30];

$E_{BOD.ins.tr} = 0.84$ – efficiency of BOD removal for insufficiently treated wastewater [30];

$MCF_{tr}, MCF_{ins.tr}, MCF_{sept}, MCF_{latr}$ – conversion factor MCF for different BOD flows (see Table 7.26);

$MCF_w = 0.1$ – conversion factor MCF for water reservoirs [1].

Organic component removed as sludge on the sludge-drying beds S_{total} were calculated on the formulas:

$$S_{total} = \left(S_{tr} + S_{ins.tr} + S_{cessp}\right), \quad (7.19)$$
$$S_{tr} = (E_{BOD.tr} - F_{aer.tr}) \times TOW_{tr\,ww} \times 365, \quad (7.20)$$
$$S_{ins.tr} = (E_{BOD.ins.tr} - F_{aer.ins.tr} - MCF_{ins.tr}) \times TOW_{ins\,tr\,ww} \times 365, \quad (7.21)$$
$$S_{cessp} = (((E_{BOD.tr} - F_{aer.tr}) + (E_{BOD.ins.tr} - F_{aer.ins.tr} - MCF_{ins.tr}))/2) \times TOW_{cessp} \times 365, \quad (7.22)$$

where $TOW_{tr\,ww}$, $TOW_{ins\,tr\,ww}$, TOW_{cessp} – organic component (BOD_5 flows) in wastewater classified as treated at the standard level, insufficiently treated and cesspools, relatively (see Table 7.25);

$F_{aer.tr}$ = 0.3 – biomass growth rate under aerobic treatment (expert estimation) [30];

$F_{aer.ins.tr}$ = 0.15 – full sludge BOD removal under aerobic treatment (expert estimation) [30].

Biodegradable parts ($F_{sl,k}$) of sludge BOD of different BOD flows were calculated based on the formulas [30]:

$$F_{sl.tr} = (E_{BOD.tr} - F_{aer.tr}) \times MCF_{sl}, \quad (7.23)$$
$$F_{sl.ins.tr} = (E_{BOD.ins.tr} - F_{aer.ins.tr} - MCF_{ins.tr}) \times MCF_{sl}, \quad (7.24)$$
$$F_{sl.cessp} = (F_{sl.tr} + F_{sl,ins.tr})/2, \quad (7.25)$$

where MCF_{sl} = 0,299 – especial conversion factor MCF for sludge-drying beds for Ukraine [34].

Table 7.26. The conversion factor MCF and biodegradable part of BOD for each of the methods of domestic sewage treatment

Treatment system	Centralized systems			Decentralized systems		Latrines	Sludge-drying beds
	Treated at the standard level	Insufficiently treated	Not treated	Septic tanks	Cesspools		
MCF	0	0.2	0.1	0.5	0.1	0.1	0.299
Biodegradable part of sewage BOD ($F_{k,ww}$)	0.0083	0.184	0.1	0.5	0.0962	0.1	-
Biodegradable part of sludge BOD $F_{k,sl}$	0.1844	0.1465	0	0	0.1655	0	-

The dominant practice of sludge treatment in Ukraine is their dehydration/drying on sludge fields /sludge-drying beds. Ukraine uses almost one method of sludge disposal – storage (> 95%). This is due to the fact that the quality of domestic sewage sludge does not correspond to standards of the heavy metals content.

The *sludge-drying beds* are the constructed sites, either on a natural or artificial basis, on which the sludge is dried. The construction of sludge-drying beds is determined depending on the hydrogeological and climatic conditions, terrain. The size of the sludge-drying beds is governing by current building codes [33]. Depth of sludge discharge is assumed to be 0.7-1.0 m [33]. The sludge discharged on the sludge cards mainly dried by the evaporation of water. Part of the water is filtered through drainage or soil (natural foundation). The dried sludge is scooped up by a bulldozer or scraper, loaded into cars and taken for further disposal. In most cases, "further disposal" means disposal in neighboring cards located on the same *sludge-drying beds*. From 1980-90, the transportation of dried sludge from sludge-drying beds was prohibited due to the high content of heavy metals, which made it impossible to use in agriculture as organic and mineral fertilizers. Dried sludge is stored on the sludge fields by embanking dams (only in Kyiv) or by attracting new territories (land). In some cases, the dried sludge is removed on the MSW landfills. However, the statistics form "1- waste" include information on the sludge deposited in solid waste disposal sites and storage on the sludge-drying beds in aggregate form because both are considered as waste disposal sites in Ukraine. Thus, the emissions from sludge deposited in solid waste disposal sites are not estimated under category 5.A. The form "1- waste" indicate that a small amount of sludge was subjected to composting and incineration. The amount of composted sludge was included in the "other waste" category (see Table 7.10, code 9030.2.9.05) and the total emissions of this group of waste were estimated and reported under category 5.B.1. The amount of incinerated sludge was indicated in the Table 7.17. The emissions from incinerated industrial and domestic sludge were estimated and reported under category 5.C.1. Information on the amount of sewage sludge application as organic and mineral fertilizers in agriculture are not available.

To estimate methane emissions from sewage sludge, the weighted average of the national BOD to methane conversion factor, MCF_{UA}, is used, determined in accordance with the ACM0014 methodology [34]. The methodology takes into account two main factors – the air temperature and the depth of the *sludge-drying beds*. According to the results of sewage treatment plants (WWTP) questioning in Ukraine, the depth of *sludge-drying beds* is 1-2 meters. The average monthly temperatures for each month of the year were different for each region of Ukraine according to the data of the Ukrainian Hydrometeorological Center. Thus, MCF_{UA} is 0.299 [30].

7.5.2.3 Uncertainties and time-series consistency

The uncertainty estimation ranges for households and the maximum methane production capacity were default ones [1], for *MCF* – calculated on the basis of [1], for the rest of the parameters – based on expert estimations [30] (Table 7.27).

Table 7.27. Uncertainty estimation ranges

Parameter	Uncertainty range, %	
	"-"	"+"
Emission factors		
Maximum methane producing capacity, kg CH_4/kg of BOD	30	30
MCF depending on the technology	21.52	21.52
Uncertainty of emission factors	36.92	36.92
Activity data		
Population, persons	5	5
BOD per capita, g/day/person	0	2.6
Proportion of population having access to sewerage	10	10
Degree of application of sewage treatment or discharge systems	10	10
Efficiency of contaminant removal by the wastewater treatment method	10	10
Uncertainty of activity data	18.03	18.21
Uncertainty of CH_4 emission	**41.1**	

7.5.2.4 Category-specific QA/QC procedures

General and detailed quality control and assurance procedures were applied:

- assessment of comparability of the *MCF* values used in the inventory with the values applied in other countries;
- comparison of emission along the time series and analysis of trends;
- comparison of activity data, emission factors, and estimation results with inventory reports of other countries.

7.5.2.5 Category-specific recalculations

In this sub-category, recalculations were carried out due to clarification of data on the population of Crimea in 2016, 2019, 2020. Results of recalculation are provided in Table 7.28.

Table 7.28. Recalculation in subcategory 5.C.1 "Waste incineration"

Year	Inventory Report, 2022 submission, kt			Inventory Report, 2023 submission, kt			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
2016	-	88.692	-	-	88.707	-	-	0.02	-
2019	-	94.625	-	-	94.631	-	-	0.01	-
2020	-	89.684	-	-	89.807	-	-	0.14	-

7.5.2.6 Category-specific planned improvements

In this sub-category, no improvements are planned.

7.5.3 Nitrous Oxide Emissions from Human Wastewater (CRF category 5.D.1.2)

7.5.3.1 Category description

Nitrous oxide emissions from sewage of domestic wastewater amounted to 991.73 kt CO_2-eq. in 2021 (3.33 kt), and their reduction with respect to 1990 (1 570.15 kt CO_2-eq.) is 36.8 %.

In 2021, consumption (gross) of protein per capita per day was 80.77 g/person/day (actual consumption), including: of vegetable origin – 38.81 g/person/day, of animal origin – 41.97 g/person/day. Information on emissions in the category for the period of 1990-2021 is shown in Fig. 7.12.

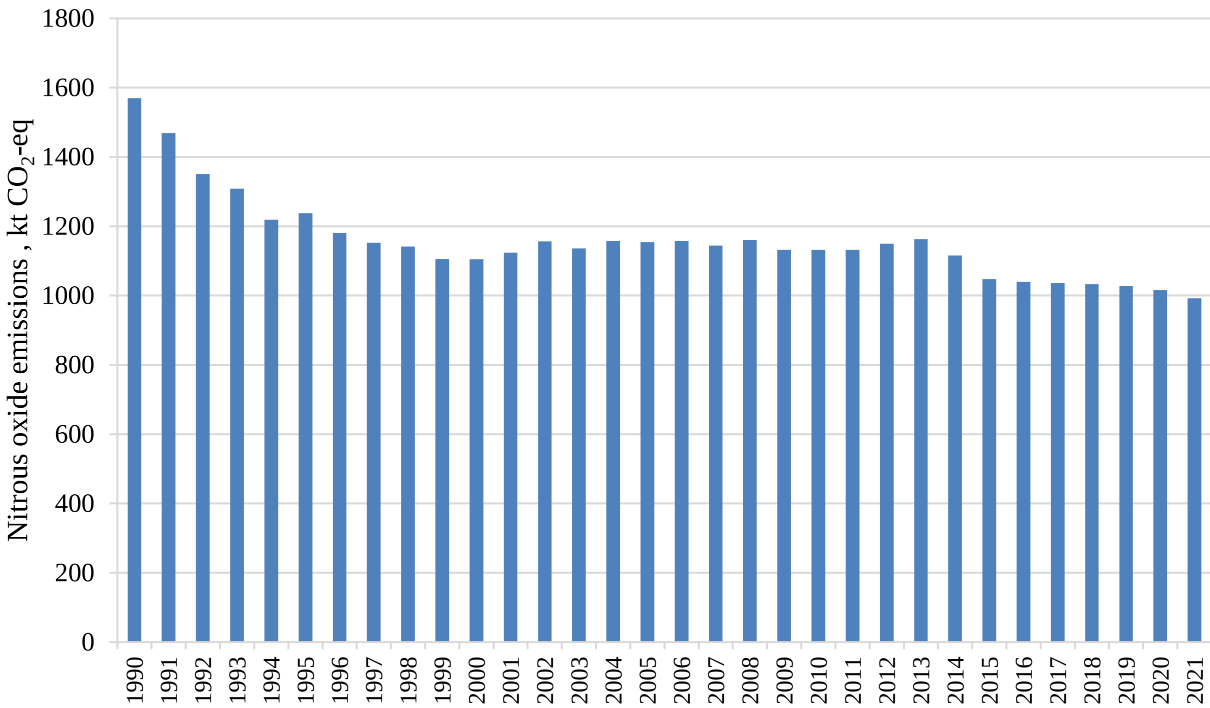


Fig. 7.12. Nitrous oxide emissions from human wastewater in Ukraine, 1990-2021

Fig. 7.12 shows that in the period of 1990-2000, there was the trend of emission reduction, which is due, first, with a reduction in the country's population, and second, to a reduction in consumption of animal products characterized by high content of protein. Since 2001, nitrous oxide emissions stabilized and changed insignificantly. The reduction in emissions in 2015 by 5.8 % compared to 2014 is due, primarily, to a sharp decline in purchasing power of population and, as a result, replacement of animal products with food of plant origin.

7.5.3.2 Methodological issues

7.5.3.2.1 General principles

Nitrous oxide emissions were divided on: indirect N_2O emissions and direct N_2O emissions. GHG emissions were calculated based on the formulas:

$$N_2O_i = N_{effluent} \times E_{f.effluent} \times 44/28, \quad (7.26)$$

$$N_2O_d = P \times T_{plant} \times F_{ind-comm} \times E_{f.plant} \times 10^{-8}, \qquad (7.27)$$

where $N_{effluent} = P_{Protein} \times F_{npr} \times F_{non-con} \times F_{ind-com} - N_{Sludge}$ – total annual amount of nitrogen in the wastewater effluent, ktN;

$P_{Protein}$ – aggregated value of total protein consumption in Ukraine estimated under food balance and decreasing rate of non-eaten part of food according to food waste statistics, kt;

$F_{npr} = 0.16$ – fraction of nitrogen in protein, kgN/kg;

$F_{non-con} = 1.1$ – factor for non-consumed protein added to the wastewater (Ukraine is a country with low GDP per capita, chapter 6.3.1.3);

$F_{ind-com} = 1$ – factor for industrial and commercial co-discharged protein into the sewer system (took into account in 5.D.2. and has no influence on estimates);

$N_{Sludge} = 0$ – nitrogen removed with sludge, ktN;

$E_{f.effluent} = 0.01$ – emission factor for effluent, kg N_2O-N/kg-N;

P – population of Ukraine, thousand persons;

T_{plant} – degree of utilization of modern centralized WWT plants (based on CH_4 emission estimation for 5.D.1 and relates to the centralized well treated WW), %;

$F_{ind-comm} = 1$ – fraction of industrial and commercial co-discharged protein (took into account in 5.D.2. and has no influence on estimates);

$E_{f.plant} = 3.2$ – emission factor, g N_2O/per/year.

Estimation of indirect and direct N_2O emissions in Ukraine in 1990-2021 is shown in Table 7.29.

Table 7.29. Indirect and direct N_2O emissions in Ukraine in 1990-2021

Year	Protein consumed (eaten), kt	Total annual amount of nitrogen in the wastewater effluent, ktN	Indirect N_2O emissions, kt	Population, thousand per.	Degree of utilization of centralized WWT plants, %	Direct N_2O emissions, kt
1990	1910.05	336.17	5.28	51891.45	8.24	0.014
1991	1787.76	314.65	4.94	52000.50	8.51	0.014
1992	1644.11	289.36	4.55	52150.35	8.80	0.015
1993	1593.23	280.41	4.41	52179.25	9.11	0.015
1994	1484.64	261.30	4.11	51921.40	9.41	0.016
1995	1507.06	265.24	4.17	51512.75	9.74	0.016
1996	1439.22	253.30	3.98	51057.75	10.25	0.017
1997	1405.08	247.29	3.89	50594.60	10.72	0.017
2001	1370.87	241.27	3.79	48662.40	12.62	0.020
2002	1410.95	248.33	3.90	48202.47	13.18	0.020
2003	1385.98	243.93	3.83	47812.95	13.70	0.021
2004	1412.78	248.65	3.91	47451.63	14.34	0.022
2005	1409.22	248.02	3.90	47105.15	15.62	0.024
2006	1413.84	248.84	3.91	46787.75	15.90	0.024
2011	1390.29	244.69	3.85	45706.05	30.86	0.045
2012	1412.31	248.57	3.91	45593.30	32.52	0.047
2013	1424.54	250.72	3.94	45489.60	26.84	0.039
2014*	1371.73	241.42	3.79	45354.34	33.27	0.048
2015*	1289.54	226.96	3.57	45156.20	35.01	0.051
2016*	1280.04	225.29	3.54	45013.45	34.83	0.051
2017*	1270.47	223.60	3.51	44835.87	25.79	0.037
2018*	1266.69	222.94	3.50	44624.83	27.01	0.039
2019*	1261.37	222.00	3.49	44389.57	27.32	0.039
2020*	1250.36	220.06	3.46	44227.84	33.17	0.047
2021*	1219.91	214.70	3.37	43884.89	32.73	0.046

*Data of the State Statistic Service of Ukraine, corrected using analytical study [36]

7.5.3.2.2 Activity data

Product consumption data are taken from the Statistical Bulletin "Balance sheets and consumption of the main types of food products by the population of Ukraine" annually published by the State Statistics Service of Ukraine. Food consumption is estimated according to the concepts and methodological approaches of the UN Food and Agriculture Organization (FAO) and is calculated as the difference of the production volume, stock changes at the end of the year, import and export amount, and use for non-food purposes.

Consumption of certain food product groups in Ukraine in 1990-2021 is shown in Table 7.30.

Table 7.30. Consumption of main food-stuffs of the population on Ukraine, 1990-2021

Food products	1990	1995	2000	2005	2010	2014*	2015*	2016*	2017*	2018*	2019*	2020*	2021*
	kt												
Animal origin													
Meat and meat products, including sub-products and raw fat	3536.7	2002.0	1611.0	1843.9	2384.0	2400.4	2246.1	2264.1	2264.9	2303.5	2324.8	2320.7	2267.4
Milk and dairy products	19363.4	12548.5	9788.8	10625.1	9469.8	9825.1	9273.4	9223.4	8765.6	8621.9	8699.6	8717.9	8627.1
Eggs (1 pc.)	14137.9	8824.9	8142.1	11207.0	13279.6	13738.6	12386.7	11768.2	11962.0	11995.7	12213.8	12000.7	11654.1
Fish and fish products	907.0	187.5	412.5	676.5	667.0	498.9	378.6	423.1	474.6	513.0	540.8	535.1	566.7
Vegetable origin													
Potato	6799.8	6376.4	6660.2	6385.6	5913.8	6061.3	6073.8	6154.1	6283.8	6081.5	5889.1	5783.9	5670.7
Vegetables and melon food crops	5318.8	4978.8	5002.0	5662.5	6581.3	7225.8	7103.0	7203.9	7002.9	7148.6	7147.0	7079.1	7104.8
Grain products	7314.3	6616.6	6141.0	5817.2	5105.9	4812.8	4559.7	4444.3	4420.5	4341.8	4235.0	4171.8	3971.0
Fruits, berries, and grape (without processing as wine)	2459.6	1720.9	1439.1	1749.6	2203.2	2320.1	2246.3	2185.4	2319.1	2522.7	2548.6	2437.3	2525.2
Sugar	2592.8	1627.1	1809.0	1794.6	1704.0	1606.1	1575.2	1461.0	1331.4	1300.4	1251.3	1200.9	1221.5
Oils	600.6	423.1	461.4	635.0	680.0	577.8	541.4	513.0	512.3	516.9	520.7	529.9	583.2

*Data of the State Statistic Service of Ukraine, corrected using analytical study [36]

7.5.3.2.3 Selection of emission factors

Protein content in *l* food product, k_l, is taken on the basis of laboratory studies of the Ukrainian Research Institute of Nutrition, the averaged data on the findings of which were provided by the State Statistics Service of Ukraine. Thus, k_l for meat products is 13.7%, dairy – 2.8%, eggs – 0.54%, fish products - 8.5%, potatoes – 1.4%, vegetables – 1.3%, flour products – 10.9%, fruit and berries – 0.83%.

The proportion of nitrogen in protein F_{NPR} is 0.16 kg of N/kg of protein [1], the nitrous oxide emission factor from discharge of DWW EF_{CTOK} – 0.01 N_2O-N/kg of N [1].

The $F_{NON\text{-}CONl}$ factor takes into account the fact that after acquisition of food products by population not all of them are used as food, as part of them following pre-treatment or when spoiled goes to landfills as waste food.

Paper [25] explores the composition of food waste as an MSW component, that also are well correlated with historical data [10, 26], the mass of dumped food waste and the ratio of the weight of individual components of food products removed to landfills to their gross consumption are estimated.

$F_{NON\text{-}CONl}$ for certain types of products can be estimated using formula [25]:

$$F_{NON\_CON_l} = MWS \cdot MWS_j \cdot B_l / P_{вал_l} \cdot 10^3, \quad (7.28)$$

where *MWS is* the mass of MSW dumped in Ukraine, t/year;
MWS_j – food waste content in the MSW composition, fraction;
B_l – the content of component l in the composition of food waste;
$P_{вал\ i}$ – gross consumption of the *l* type of food product by population, kg/year.

According to [25], the proportion of dumped food components that were not actually eaten, and nitrogen in their composition was not to discharged into DWW is the following: for meat products - 7.6%, dairy – 1.3%, bread – 2.6%, potatoes – 10.6%, fruit and vegetables – 17.6%, fish products – 8.4%.

7.5.3.3 Uncertainties and time-series consistency

Ranges of uncertainty estimates for all the parameters were taken by default [1] and are presented in Table 7.31.

Table 7.31. Uncertainty estimation ranges

Parameter	Estimated uncertainty	
	"-"	"+"
Emission factors		
Emission factor, kg of N_2O-N/kg of N	50	50
Proportion of nitrogen in protein, kg of N/kg of protein	3.61	3.61
Loss of food products factor, fraction	5	5
Uncertainty of emission factors	50.38	50.38
Activity data		
Population, pers.	5	5
Food consumption, thousand tons	5	5
Uncertainty of activity data	7.07	7.07
Standard uncertainty of N_2O emissions	**50.63**	**50.78**

7.5.3.4 Category-specific QA/QC procedures

General quality control and assurance procedures were applied - comparison of emissions along the time series and trend analysis, as well as comparison of activity data, emission factors, and estimation results with inventory reports of other countries.

Together with leading specialists of the Department of Statistics of Agriculture and the Environment of the State Statistics Service of Ukraine, a comparative analysis of state statistics on protein consumption by the population of Ukraine with FAO data.

Comparison of data of the State Statistics Service of Ukraine with statistics of the Food and Agriculture Organization of the United Nations (FAO)[11] over the comparable time series of 1992-2011 demonstrated data divergence within the range of 0.1-5.2%. Detailed information is presented in Fig. 7.13.

The difference of data is seen as acceptable, taking into account the estimation range of GHG emission uncertainties in this category, and is due to the fact that the FAO statistics take into account the protein content for a more extensive classification of food product groups.

[11] http://faostat3.fao.org/faostat-gateway/go/to/download/FB/FB/E

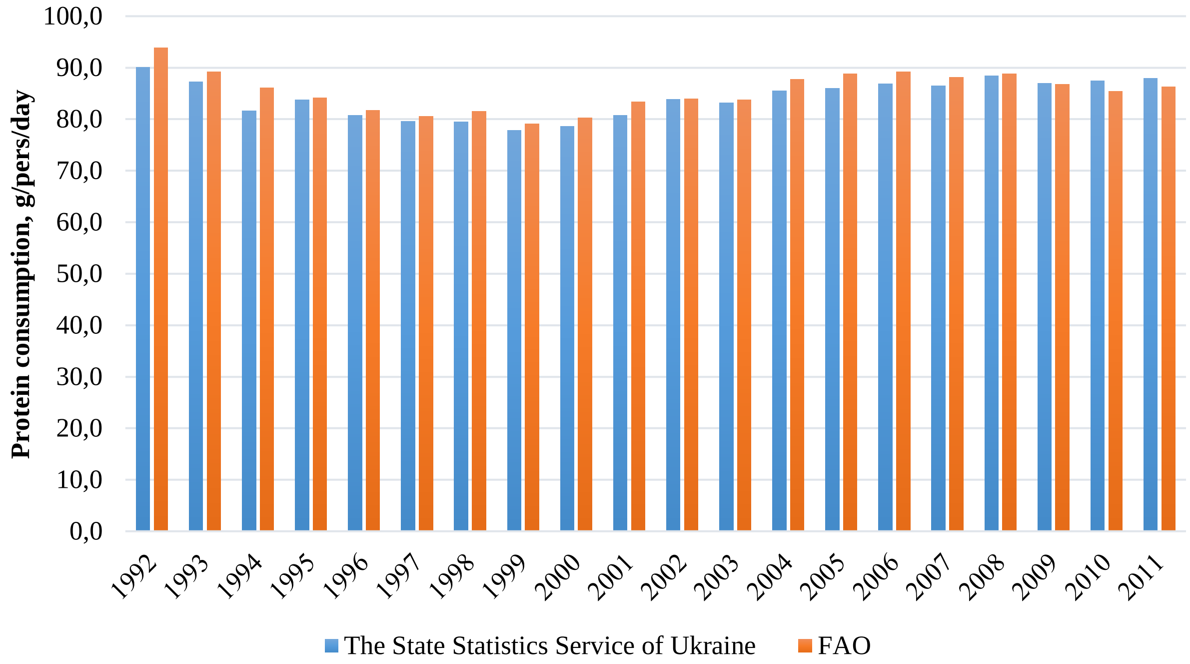


Fig. 7.13. Consumption of protein by the population of Ukraine, 1992-2011: columns on the left - the State Statistics Service of Ukraine, on the right – FAO

7.5.3.5 Category-specific recalculations

In this sub-category, recalculations were made due to clarification of data on the population of Crimea in 2016, 2020. Results of recalculation are provided in Table 7.32.

Table 7.32. Recalculations in subcategory 5.D.1.2 "Nitrous Oxide Emissions from Human Waste Water"

Year	Inventory Report, 2022 submission, kt			Inventory Report, 2023 submission, kt			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
2016	-	-	3.4886	-	-	3.4890	-	-	0.01
2020			3.4081			3.4112			0.09

7.5.3.6 Category-specific planned improvements

In this sub-category, no improvements are planned.

7.5.4 Industrial Wastewater Treatment and Discharge (CRF category 5.D.2)

7.5.4.1 Category description

The section accounts for emissions of methane and nitrous oxide resulting from treatment of industrial wastewater.

Based on estimations of the current inventory, in 2021 GHG emissions from treatment of industrial wastewater amounted to 1 207.33 kt CO_2-eq, the decrease with respect to 1990 (1 731.87 kt CO_2-eq) is 30.29 % and decrease in comparison with 2020 is 12.78 % (see Fig. 7.14). Of these, methane emissions – 1 134.92 kt CO_2-eq (45.39 kt), nitrous oxide – 72.41 kt CO_2-eq (0.243 kt).

Due to armed aggression of the Russian Federation against Ukraine, in particular occupation of the territories of the Autonomous Republic of Crimea, the city of Sevastopol and parts of the Donetsk and Luhansk regions the decrease of GHG emissions in the subcategory was equal to 16.09 %

in 2015 and 11.61 % in 2016 compared to 2014, certain influence on the trend had significant increase in water use tariffs also.

For details on GHG emissions at industrial wastewater treatment, see Fig. 7.14.

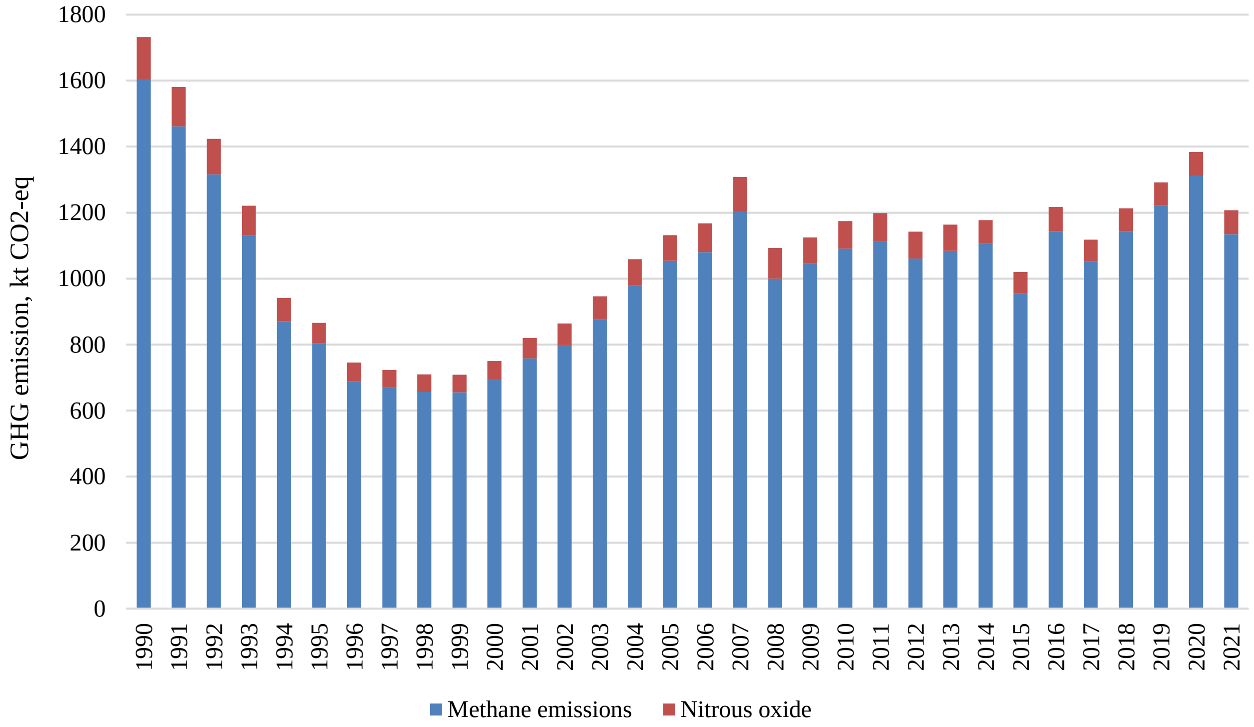


Fig. 7.14. GHG emissions from industrial sewage treatment in Ukraine, 1990-2021

Trends of GHG emissions from treatment of industrial wastewater, in general, are correlated with the growth of industrial production in the country. It should be noted that the increase in emissions in 2007 by 12.86 % in relation to 2006 was due to a sharp increase in the volume of wastewater generation in the sectors of heavy and chemical industries, as well as in the energy sector supporting their energy needs.

In 2021, 21.93 % of methane emissions were caused directly by wastewater treatment, and 78.07 % – by treatment of their sludge. Methane emissions from sewage directly, as well as from their sludge are shown in Fig. 7.15.

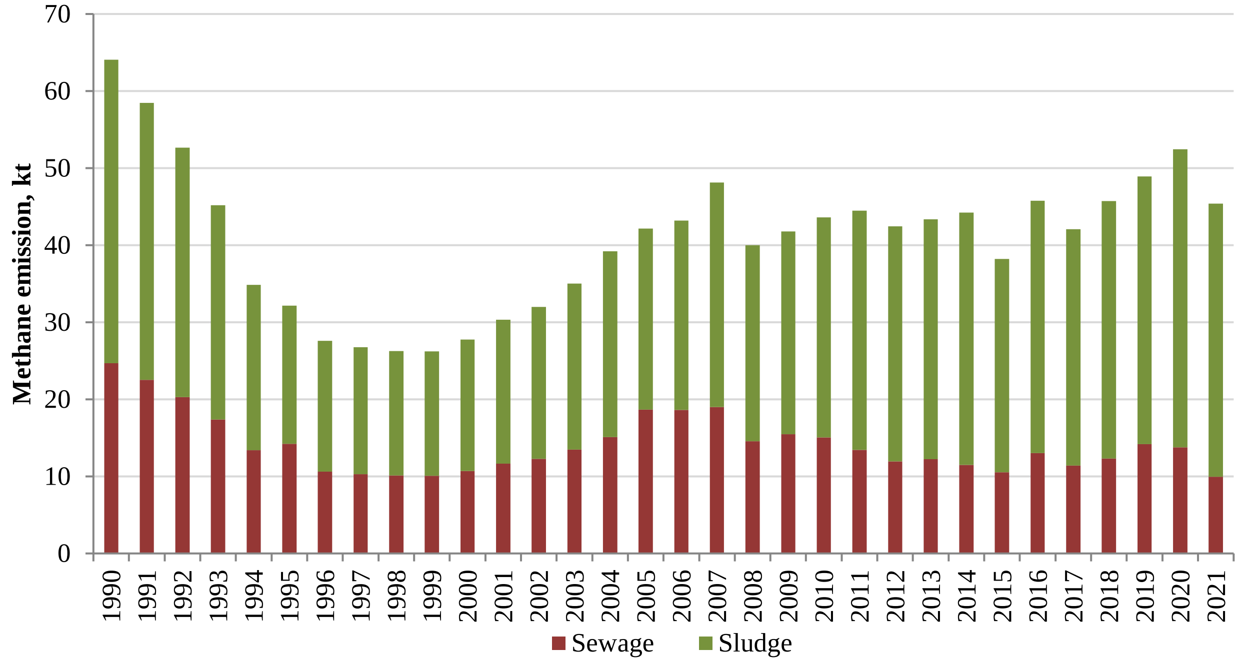


Fig. 7.15. Methane emissions from industrial sewage and sludge treatment in Ukraine, 1990-2021

GHG emissions from wastewater treatment by industry are presented in Fig. 7.16. In 2021, the largest contribution was made by food, meat and dairy, pulp and paper industries – 596.09, 172.94, and 96.85 kt CO_2-eq., respectively.

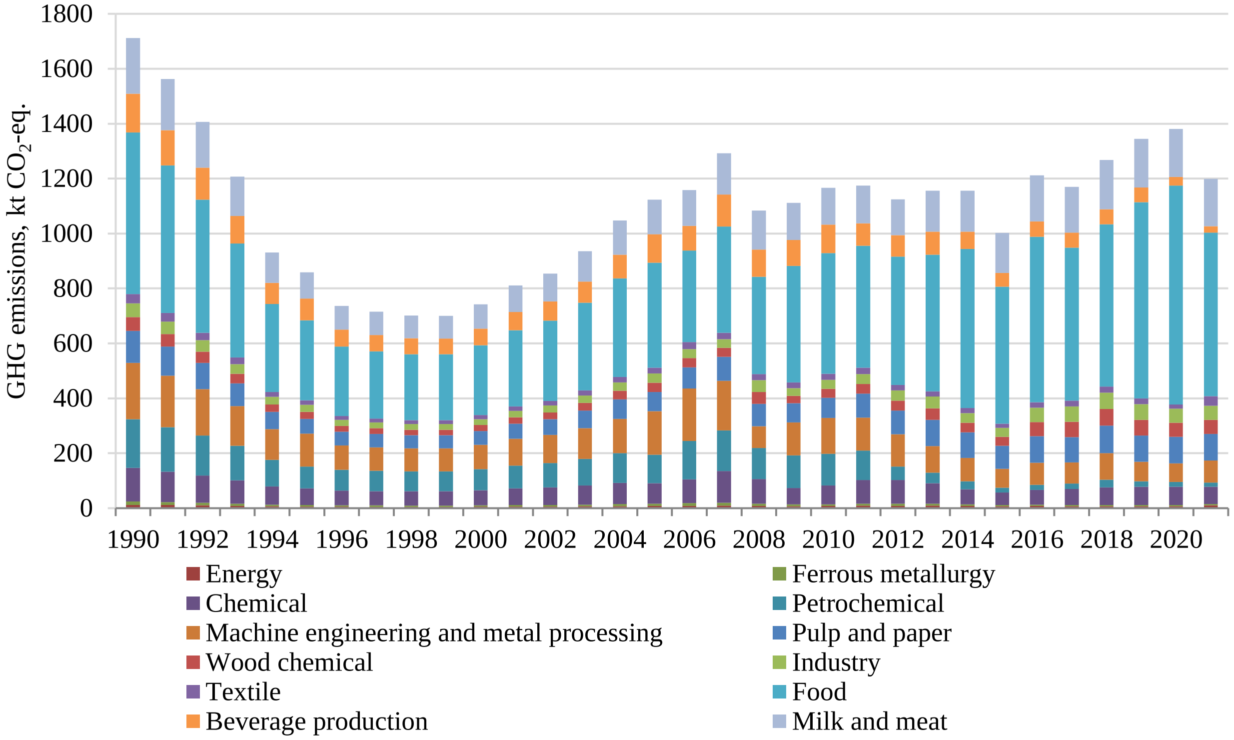


Fig. 7.16. GHG emissions from industrial sewage treatment by industries in Ukraine, 1990-2021

7.5.4.2 Methodological issues

7.5.4.2.1 General principles

For treatment, industrial wastewater is mainly directed to a centralized sewage system, however can also be discharged from enterprises directly to the water receiver. In the first case, wastewater is treated in the same way as domestic wastewater, collected by a centralized sewer system. In the second case, wastewater can enter into water receivers without treatment or be treated at local treatment plants of industrial enterprises.

Industrial wastewater that is biologically treated goes through all stages, similar to the treatment of domestic wastewater at central aeration stations. Therefore, the regularities of decomposition of organic matter and the organic extraction with the sludge are common, which allows with a certain assumption to take the appropriate coefficients as for domestic wastewater.

Mechanical methods of industrial wastewater treatment can be used as a preliminary treatment of large solids and floating substances (fats, oils, petroleum products, etc.). The regularities of contaminants removing are mainly similar to those in the treatment of domestic wastewater.

In some cases, before wastewater discharging into water bodies, biological pre-treatment or additional treatment of industrial wastewater is applied, including treatment in bio-pounds, filtration fields, etc. Removal of contaminants in such cases occurs in conditions close to natural, and are less intensive, compared to aeration at central treatment plants.

Estimation of methane and nitrous oxide emissions from treatment of industrial wastewater was made in accordance with the procedure set out in the research paper: "Study of methane and nitrous oxide emissions from waste water treatment and development of methods to determine national emission factors", 2012 [30].

Methane emissions from industrial sewage treatment were determined under formula [30]:

$$E_{CH4,j} = \sum_k M_{COD,j} \times F_{anaer,j,k} \times B_0, \qquad (7.29)$$

where $M_{COD,j}$ – total amount of organic component (COD) in the *j* type industry wastewater, kt;

$F_{anaer,j,k}$ – biodegradable part of COD from the *j* type industry that produce methane by treating wastewater/sludge of different treatment methods *k* (aeration plants, bio-pounds (additional treatment), physico-chemical treatment, mechanical treatment, open ponds), %;

$B_0 = 0.25$ – maximum methane production capacity, kg of CH_4/kg of COD [1].

The total amount of organic component (COD) in wastewater were determined by formula [34]:

$$M_{COD,j} = P_i \times C_{COD,i} \times q_i, \qquad (7.30)$$

where P_i – release of *i* type products, accounting units; data of the State Statistics Service of Ukraine;

$C_{COD,i}$ – concentration of COD in industrial wastewater, resulting from manufacturing *i* type products, mg/l; taken from tables of consolidated standards;

q_i – average annual wastewater volume discharged by an industrial enterprise from manufacturing *i* type products, m^3 per accounting units; taken from tables of consolidated standards.

Based on data of the State Agency for Water Resources of Ukraine (State Water Agency) on discharge of pollutants into surface water bodies from statistical form No. 2-TP (water management), industries with the largest amounts of chemical oxygen demand (COD) and total nitrogen were identified: energy, ferrous metallurgy, chemical industry, petrochemical industry, mechanical engineering industry and metal processing, pulp and paper industry, resin industry, construction materials industry, textile industry, food industry, beverage industry, meat-and-milk, and fishing industries.

7.5.4.2.2 Activity data

Generation of organic pollutants getting into industrial wastewater was calculated on the basis of data of the State Statistics Service of Ukraine on the degree of key commodity group production and consolidated water consumption and sewage standards [30] taking into account the analytical study [36]. The average annual quantity of wastewater generated per unit of output was taken from tables of consolidated standards.

The concentration of COD and total nitrogen in industrial wastewater (the general discharge) resulted from production of the *i* type of products were taken based on data on the composition of wastewater. Data on consolidated standards are considered since the most Ukrainian industrial production has been formed in Soviet period.

The total amount of wastewater by industries, as well as COD formation and nitrogen in them along the time series of 1990-2021 are shown in Tables 7.34-7.38.

7.5.4.2.3 Selection of emission factors

Distribution of COD flows (see Table 7.35) of industrial wastewater depending on the method of their treatment *k* was determined based on data of the State Water Agency of Ukraine on discharges of pollutants into surface water bodies in statistical form No. 2-TP (water management).

Biodegradable parts of COD in wastewater from the *j* type industry treated by different treatment methods *k* were calculated on the formula [30]:

$$F_{ww,anaer.j} = \sum_k (F_{COD,tr,j,k} + F_{COD,uns\,tr,j,k} \times \varphi_{uns.tr}) \times E_{COD,k} \times MCF_k, \qquad (7.31)$$

Biodegradable parts of COD that produce methane by treating/dehydration sludge were calculated on the formula [30]:

$$F_{sl,anaer.j} = \sum_k (F_{COD,tr,j,k} + F_{COD,uns\,tr,j,k} \times \varphi_{uns.tr}) \times E_{COD,k} \times (1 - F_{aer,k}) \times MCF_{UA}, \quad (7.32)$$

where $F_{COD,tr,j,k}$ – biodegradable parts of COD in wastewater classified as treated at the standard level being treated by each of the methods *k*, from the *j* type industry, %;

$F_{COD,uns\,tr,j,k}$ – biodegradable parts of COD in wastewater classified as insufficiently treated being treated by each of the methods *k*, from the *j* type industry, %;

$\varphi_{uns.tr}$ – degree of wastewater treatment classified as insufficiently treated for each of the methods *k*, %; accounts for 80 % (except for wastewater, which are additional treated, where such an indicator is 100 %);

$E_{COD,k}$ – efficiency of COD removal for each of the treatment methods *k*, %, [30], (table 7.33);

$F_{aer,k}$ – the part of COD in wastewater, which is degradable in oxic/aerobic conditions by each of the treatment methods *k*, %; for the part of COD flow biologically treated at wastewater treatment plants it equals 30 %; for bio-ponds and others it is not taken into account, because the system does not sludge treated; for physical, chemical and mechanical treatment it is assumed to be zero;

MCF_k – conversion factor MCF for different COD flows (table 7.33);

MCF_{sl} – 0.299 – especial conversion factor MCF for sludge-drying beds for Ukraine [30].

Organic component (COD flow) removed as sludge on the sludge-drying beds $S_{COD,total,j}$ were calculated on the formula:

$$S_{COD,total,j} = \sum_k (M_{COD,tr,j,k} + M_{COD,uns\,tr,j,k} \times \varphi_{uns.tr}) \times E_{COD,k} \times (1 - F_{aer,k}), \quad (7.33)$$

where $S_{COD,tr,j,k}$, $S_{COD,uns\,tr,j,k}$ – the amount of organic component (COD flows) in wastewater classified as treated at the standard level and insufficiently treated, relatively that being treated by each of the methods *k*, from the *j* type industry.

MCF, the COD and nitrogen removal efficiency (see Table 7.33) for each of the methods of industrial wastewater treatment were selected on the basis of the procedure [34], taking into account sanitary rules and standards of surface water protection from pollution [35].

The MCF values for different type of industrial wastewater treatment were taken by default according to 2006 IPCC Guidelines (vol. 5, chapter 6, tables 6.3, 6.8). The MCF for industrial wastewater normatively treated at central aeration stations is assumed to be zero, for insufficiently treated wastewater the value of this coefficient is taken 0.2. For the part of industrial wastewater treated in biological ponds, filtration fields, etc., the conservative MCF value of 0.05 was accepted. For the part of wastewater physical and chemical treated, the MCF value is assumed to be zero. It is considered, that in the technological cycle of physical and chemical treatment there are no appropriate conditions for the biochemical decomposition of organic matter with the methane emission. The mechanical treatment may lead to create the conditions of methane emission at the treatment plants (due to the insufficiently efficient sludge removal from settling tanks, etc.), thus for such systems, the MCF value of 0.05 was accepted. For the share of industrial wastewater discharged into open reservoirs (seas, rivers, lakes) the MCF value was taken by default 0.1.

Table 7.33. The methane conversion factor MCF and COD and nitrogen removal efficiency for each of the methods of industrial sewage treatment

The methods of industrial waste water treatment (*k*)		**MCF**	**COD removal efficiency ($E_{COD,k}$), %**	**Nitrogen removal efficiency, %**
Aeration plants	*water treated at the standard level*	0	83.9	19.6

The methods of industrial waste water treatment *(k)*		**MCF**	**COD removal efficiency** ($E_{COD,k}$), **%**	**Nitrogen removal efficiency, %**
	insufficiently treated water	0.2		
Bio-pounds (additional or pre-treatment)	*wastewater*	0.05	3.0	2.7
Physico-chemical treatment	*wastewater*	0.0	80.0	57.0
Mechanical treatment	*wastewater*	0.05	34.0	0.0
Open ponds	*wastewater*	0.1	-	-
Sludge drying beds	*Sludge*	0.299	-	-

In determining nitrous oxide emissions from wastewater, only indirect emissions from nitrogen compounds discharged with wastewater into water bodies are accounted for. Direct nitrous oxide emissions from wastewater treatment with nitrodenitrification methods are not accounted for, since application of such methods in wastewater treatment is not a common practice in Ukraine.

Distribution of nitrogen flows from industrial wastewater depending on the treatment method (see Table 7.35) was held based on data of the State Water Agency of Ukraine on discharges of pollutants into surface water bodies in statistical form No. 2-TP (water management).

Determination of the total weight of nitrous oxide emitted as a result of nitrogen discharge in composition of industrial wastewater into open reservoirs was performed based on data on the degree of nitrogen removal from treatment systems according to [32]. The N_2O emission factor at wastewater discharge is by default 0.005 kg of N_2O-N/kg of N in accordance with [1].

Table 7.34. Volume of industrial wastewater by industries

Industry	Volume of sewage, million m^3															
	1990	1995	2000	2005	2010	2011	2012	2013	2014*	2015*	2016*	2017*	2018*	2019*	2020*	2021*
Energy	404.1	193.2	174.6	253.4	254.6	286.3	278.1	281.5	257.9	225.7	266.6	215.9	235.5	228.3	221.2	283.9
Ferrous metal-lurgy	263.6	126.0	113.9	165.2	161.9	176.4	185.1	179.5	142.2	116.2	133.6	120.6	125.8	126.7	118.9	122.3
Chemical	119.3	57.6	55.1	75.1	64.5	91.6	84.8	65.9	49.3	37.2	44.3	44.6	48.7	50.1	52.0	49.4
Petrochemical	136.7	65.3	59.0	85.7	88.3	80.6	54.2	44.1	36.3	30.5	31.7	29.5	32.0	30.6	30.7	31.4
Machine engi-neering and metal pro-cessing	1191.9	569.7	514.9	747.3	718.4	719.7	722.0	652.0	588.0	529.2	569.2	537.5	587.9	539.9	520.5	586.1
Pulp and paper	259.1	123.9	111.9	162.5	173.6	180.5	183.2	191.0	187.3	160.0	185.4	179.5	195.0	183.7	188.1	196.8
Wood chemical	36.2	17.3	15.6	22.7	23.6	26.3	26.3	23.6	23.9	22.2	26.7	26.7	30.4	27.5	26.2	27.7
Industry	935.9	447.4	404.3	586.8	618.8	706.2	771.6	948.5	733.0	598.4	840.8	880.1	1016.3	1107.9	1074.6	1102.3
Textile	23.9	11.4	10.3	15.0	13.7	14.9	14.0	13.3	13.2	13.1	15.1	16.2	16.8	15.6	15.7	16.4
Food	260.8	124.6	112.7	163.5	183.0	194.3	195.7	180.9	212.7	181.9	224.0	230.2	242.2	264.1	268.5	233.4
Beverage pro-duction	117.7	56.2	50.8	73.8	87.3	71.2	70.9	74.4	60.2	49.6	53.5	53.2	56.4	51.4	53.3	48.3
Milk and meat	79.3	37.9	34.3	49.7	51.9	52.6	54.7	58.9	60.6	57.8	67.3	64.7	71.8	72.1	74.7	73.0
Fish	5.6	2.7	2.4	3.5	3.6	3.2	3.3	3.5	2.1	1.5	1.8	1.7	1.9	1.9	2.0	1.9
Total	**3834.0**	**1833.2**	**1659.8**	**2404.2**	**2443.2**	**2603.9**	**2644,0**	**2717.2**	**2366.5**	**2023.5**	**2460.0**	**2400.3**	**2660.4**	**2699.9**	**2646.6**	**2773.0**

*Data corrected using analytical study

Table 7.35. COD generation in industrial wastewater

Industry	COD generation, kt															
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy	17.5	8.4	7.6	11.0	11.2	13.9	13.8	14.6	14.3	13.1	15.0	13.1	14.0	13.8	12.9	21.5
Ferrous metallurgy	11.9	5.7	5.1	7.4	7.3	7.9	8.3	8.1	6.4	5.2	6.0	5.4	5.7	5.7	5.4	5.5
Chemical	90.4	43.6	41.3	55.9	50.7	65.6	59.4	50.8	38.4	31.1	37.4	44.3	47.6	48.7	48.5	46.9
Petrochemical	162.8	77.8	70.3	102.1	100.8	88.5	41.9	32.6	24.9	13.4	14.6	15.0	22.9	15.1	14.6	15.7
Machine engineering and metal processing	324.4	155.1	140.1	203.4	193.5	192.0	183.5	164.9	155.2	137.1	150.1	142.9	159.2	145.4	139.6	158.1
Pulp and paper	112.2	53.7	48.5	70.4	75.5	78.1	79.7	84.3	83.4	72.3	83.5	80.3	87.6	83.5	85.3	88.9
Wood chemical	77.3	36.9	33.4	48.4	50.4	55.9	56.1	49.8	50.4	46.4	54.1	52.7	58.2	52.0	48.8	55.8
Industry	101.1	48.3	43.7	63.4	68.4	72.8	76.2	87.9	74.4	62.6	82.8	84.2	94.8	102.1	101.8	105.3
Textile	27.6	13.2	11.9	17.3	15.5	16.2	14.4	13.8	13.1	12.1	14.1	14.9	15.2	14.0	14.0	15.1
Food	1078.2	515.4	465.8	676.0	753.4	804.1	791.9	729.6	824.6	705.8	857.1	865.7	908.7	974.3	974.5	877.1
Beverage production	118.1	56.4	51.0	74.0	90.5	72.6	71.0	74.8	60.7	50.5	55.3	54.9	57.5	52.0	52.3	49.6
Milk and meat	159.6	76.3	69.0	100.1	104.5	105.9	110.0	118.5	121.6	116.1	135.1	130.1	144.3	144.3	149.5	145.9
Fish	9.9	4.7	4.3	6.2	6.3	5.6	5.9	6.1	4.0	2.8	3.2	3.1	3.5	3.4	3.6	3.5
Total	**2290.9**	**1095.4**	**991.9**	**1435.6**	**1528.0**	**1579.2**	**1512.1**	**1435.8**	**1471.3**	**1268.5**	**1508.2**	**1506.5**	**1619.2**	**1654.4**	**1650.6**	**1588.8**

Table 7.36. Nitrogen generation in industrial wastewater

Industry	Nitrogen generation, kt															
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy	1.4	0.7	0.6	0.9	0.9	1.1	1.1	1.1	1.1	1.0	1.2	1.0	1.1	1.1	1.0	1.6
Ferrous metal-lurgy	1.8	0.9	0.8	1.2	1.1	1.2	1.3	1.3	1.0	0.8	0.9	0.8	0.9	0.9	0.8	0.9
Chemical	14.8	7.1	6.4	8.1	8.3	9.9	8.5	8.0	6.2	5.4	5.6	5.0	5.0	6.0	6.8	6.3
Petrochemical	3.2	1.5	1.4	2.0	2.1	1.9	1.2	0.9	0.7	0.6	0.8	0.7	0.7	0.7	0.7	0.9
Machine engi-neering and metal pro-cessing	2.4	1.1	1.0	1.5	1.4	1.4	1.4	1.3	1.2	1.1	1.1	1.1	1.2	1.1	1.0	1.2
Pulp and paper*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood chemical	1.0	0.5	0.4	0.6	0.6	0.7	0.7	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.6	0.7
Industry*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Textile	0.6	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4
Food	14.4	6.9	6.2	9.0	9.9	10.8	10.4	9.6	10.1	9.0	10.2	9.7	10.0	9.9	9.5	9.2
Beverage pro-duction	13.0	6.2	5.6	8.2	9.4	7.6	7.5	8.4	6.0	4.9	5.2	5.3	5.3	4.2	4.9	3.9
Milk and meat	10.0	4.8	4.3	6.3	6.6	6.8	7.0	7.6	7.8	7.5	8.8	8.5	9.5	9.6	9.9	9.8
Fish	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	**62.9**	**30.1**	**27.2**	**38.3**	**40.8**	**41.9**	**39.5**	**39.1**	**35.0**	**31.2**	**34.9**	**33.0**	**34.7**	**34.5**	**35.7**	**34.7**

* - nitrogen generation volume less than 0.1 thousand tons

Table 7.37. COD content in industrial wastewater depending on the method of its treatment, 2021

Industry	Waste water COD, %					Sludge COD, %			
	Aeration plants	Bio-pounds	Physico-chemical treatment	Mechanical treatment	Open ponds	Aeration plants	Bio-pounds	Physico-chemical treatment	Mechanical treatment
Energy	2,15	0,00	0,57	3,14	94,15	26,59	0.00	11,72	61,69
Ferrous metallurgy	6,71	0,01	0,01	15,06	78,22	24,70	0.00	0,03	75,27
Chemical	74,62	0,14	5,43	3,56	16,25	85,41	0.00	8,99	5,60
Petrochemical	84,48	0,16	0,00	0,04	15,33	99,94	0.00	0,00	0,06
Machine engineering and metal processing	15,26	0,03	3,86	31,02	49,84	21,75	0.00	9,06	69,19
Pulp and paper	79,18	0,15	1,08	3,95	15,64	91,98	0.00	1,79	6,23
Wood chemical	59,66	0,11	0,00	18,41	21,81	70,48	0.00	0,00	29,52
Construction materials	4,30	0,01	4,00	28,99	62,70	7,63	0.00	11,71	80,66
Textile	68,51	0,14	0,00	9,35	22,00	82,78	0.00	0,00	17,22
Food	76,77	0,15	0,51	2,25	20,32	95,11	0.00	0,94	3,94
Beverage production	68,89	0,13	0,00	5,80	25,18	89,74	0.00	0,00	10,26
Milk and meat	81,05	0,16	0,00	1,16	17,64	98,01	0.00	0,00	1,99
Fish	86,01	0,16	0,00	0,00	13,82	100,00	0.00	0,00	0,00

Table 7.38. Nitrogen content in industrial wastewater, %, 2021

Industry	Treatment method				
	Aeration plants	Aggregators, irrigation fields	Physico-chemical treatment	Mechanical treatment	Open ponds
Energy	0.97	0.06	0.14	4.37	94.45
Ferrous metallurgy	4.25	0.27	0.00	29.29	66.19
Chemical	73.82	4.70	3.01	10.82	7.65
Petrochemical	73.33	4.67	0.00	0.09	21.91
Machine engineering and metal processing	6.34	0.40	0.90	39.59	52.76
Pulp and paper	0.00	0.00	0.00	0.00	0.00
Wood chemical	47.70	3.04	0.00	45.19	4.07
Construction materials	2.00	0.13	1.04	41.31	55.52
Textile	64.40	4.10	0.00	26.98	4.52
Food	43.29	2.76	0.16	3.90	49.90
Beverage production	16.27	1.04	0.00	4.20	78.49
Milk and meat	77.57	4.94	0.00	3.41	14.08
Fish	94.01	5.99	0.00	0.00	0.00

7.5.4.3 Uncertainties and time-series consistency

Ranges of uncertainty estimates for the maximum methane production capacity B_0 and the N_2O emission factor (EF) are taken by default [1], for the other parameters – in accordance with [30], and they are presented in Table 7.39.

Table 7.39. Uncertainty estimation ranges

Parameter	Uncertainty range, %	
	"-"	"+"
Emission factors		
B_0, kg of CH_4/kg of COD	30	30
MCF for CH_4	27.8	27.8
EF, kg of N_2O-N/kg of N	50	50
Uncertainty of CH_4 emission factors	40.7	40.7
Uncertainty of N_2O emission factors	50.0	50.0
Activity data		
Volume of waste water, m^3	0	10
COD generated, kg/m^3	10	10
Nitrogen generated, kg/m^3	10	10
Production volumes for individual commodity groups	5	5
Specific sewage standards at production of certain commodity groups	15	15
Efficiency of contaminant removal by wastewater treatment method	10	10
Uncertainty of activity data (CH_4)	23.6	23.6
Uncertainty of activity data (N_2O)	23.6	23.6
Standard uncertainty of CH_4 emissions	**46.9**	
Standard uncertainty of N_2O emissions	**55.2**	

7.5.4.4 Category-specific QA/QC procedures

For estimation of emissions in the sub-category, the general ad detailed quality control procedures were applied:

- assessment of comparability of the MCF values used in the inventory with the values applied in other countries;
- comparison of emission along the time series and analysis of trends.

7.5.4.5 Category-specific recalculations

In this category, recalculations were made due to clarification and taking into account additional data on the release of certain type of products P_i for each industry for the entire time series. Results of recalculation are provided in Table 7.40.

Table 7.40. Recalculations in subcategory 5.D.1.2 "Industrial Wastewater Treatment and Discharge"

Year	Inventory Report, 2022 submission, kt			Inventory Report, 2023 submission, kt			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	-	63.63	0.40	-	64.08	0.44	-	0.70	8.31
1991	-	58.10	0.37	-	58.47	0.40	-	0.65	8.31
1992	-	52.37	0.33	-	52.65	0.36	-	0.54	8.31
1993	-	44.92	0.28	-	45.17	0.31	-	0.55	8.31
1994	-	34.62	0.22	-	34.85	0.24	-	0.67	8.31
1995	-	31.79	0.19	-	32.17	0.21	-	1.18	8.59
1996	-	27.36	0.17	-	27.59	0.19	-	0.83	8.31
1997	-	26.53	0.17	-	26.76	0.18	-	0.86	8.31
1998	-	26.03	0.16	-	26.27	0.18	-	0.94	8.31
1999	-	25.96	0.16	-	26.23	0.18	-	1.04	8.31
2000	-	27.49	0.17	-	27.77	0.19	-	1.04	8.31
2001	-	30.03	0.19	-	30.35	0.21	-	1.04	8.31
2002	-	31.63	0.20	-	31.98	0.22	-	1.12	8.31
2003	-	34.62	0.22	-	35.04	0.24	-	1.22	8.31
2004	-	38.82	0.25	-	39.20	0.27	-	0.99	8.31
2005	-	41.71	0.25	-	42.15	0.26	-	1.05	5.36
2006	-	42.33	0.27	-	43.20	0.29	-	2.05	7.63
2007	-	47.63	0.32	-	48.14	0.35	-	1.09	9.67
2008	-	40.79	0.29	-	39.98	0.31	-	-1.98	8.06
2009	-	43.18	0.26	-	41.80	0.27	-	-3.18	4.47
2010	-	44.14	0.26	-	43.62	0.28	-	-1.16	8.31
2011	-	43.99	0.26	-	44.50	0.29	-	1.15	12.89
2012	-	42.24	0.25	-	42.44	0.27	-	0.47	10.04
2013	-	42.72	0.24	-	43.38	0.27	-	1.56	10.37
2014	-	41.80	0.22	-	44.21	0.24	-	5.78	9.16
2015	-	34.98	0.19	-	38.23	0.22	-	9.28	11.55
2016	-	36.82	0.21	-	45.75	0.25	-	24.24	20.26
2017	-	31.88	0.17	-	42.05	0.22	-	31.90	27.40
2018	-	34.52	0.19	-	45.72	0.23	-	32.44	22.66
2019	-	35.32	0.18	-	48.92	0.23	-	38.49	25.43
2020	-	38.36	0.19	-	52.45	0.25	-	36.72	26.84

7.5.4.6 Category-specific planned improvements

In this sub-category, no improvements are planned.

8 OTHER (CRF SECTOR 7)

Ukraine does not report emissions in this sector.

9 INDIRECT CO_2 AND NITROUS OXIDE EMISSIONS

For the purpose of paragraph 29 of decision 24/CP.19, Ukraine has elected to report indirect nitrous oxide emissions.

The calculation of indirect nitrous oxide emissions from Energy and IPPU sectors was performed in accordance with 2006 IPCC Guidelines [1] (Chapter 7.3, Volume 1) for all categories of these sectors where NO_x emissions are allocated, using default emission factors.

The basic data on the results of indirect nitrous oxide emissions calculated for the whole time series see in table below.

Year	INDIRECT EMISSIONS (kt)		INDIRECT EMISSIONS (kt)
	N_2O		N_2O
	ENERGY	**IPPU**	**Total**
1990	11.598	0.196	11.793
1991	10.021	0.172	10.193
1992	8.813	0.152	8.964
1993	7.450	0.125	7.575
1994	6.333	0.101	6.434
1995	5.884	0.085	5.969
1996	5.416	0.096	5.513
1997	4.932	0.105	5.037
1998	4.629	0.092	4.721
1999	4.325	0.099	4.424
2000	3.990	0.107	4.097
2001	4.020	0.108	4.128
2002	4.023	0.122	4.145
2003	4.110	0.127	4.237
2004	4.182	0.118	4.301
2005	4.149	0.135	4.284
2006	4.459	0.136	4.595
2007	4.225	0.164	4.389
2008	4.216	0.151	4.367
2009	3.514	0.103	3.617
2010	3.572	0.129	3.700
2011	3.713	0.159	3.873
2012	3.549	0.158	3.707
2013	3.560	0.128	3.688
2014	3.114	0.109	3.223
2015	2.600	0.085	2.685
2016	2.680	0.095	2.775
2017	2.664	0.075	2.738
2018	2.749	0.073	2.822
2019	2.694	0.102	2.796
2020	2.549	0.113	2.662
2021	2.491	0.119	2.610

Indirect CO_2 emissions was not estimated.

10 RECALCULATIONS AND IMPROVEMENTS

Recalculations in current NIR were performed in the IPPU, Agriculture, LULUCF and Waste sectors. The results of review of GHG emissions and removals are presented in table 10.1.

Table 10.1. Recalculation of total GHG emisisons in comparison with 2020 submission

	NIR 2022 (including LULUCF), kt CO2-eq.	NIR 2023 (including LULUCF), kt CO2-eq.	Changes, %	NIR 2022 (excluding LULUCF), kt CO2-eq.	NIR 2023 (excluding LULUCF), kt CO2-eq.	Changes, %
1990	910 983	911 401	0,05	942 390	942 808	0,04
1991	816 433	816 839	0,05	856 026	856 432	0,05
1992	761 723	761 961	0,03	801 043	801 281	0,03
1993	678 142	678 276	0,02	710 953	711 087	0,02
1994	567 695	567 932	0,04	604 681	604 918	0,04
1995	529 765	529 986	0,04	561 890	562 112	0,04
1996	487 330	487 701	0,08	515 054	515 425	0,07
1997	476 887	477 169	0,06	499 355	499 636	0,06
1998	452 577	452 818	0,05	480 676	480 917	0,05
1999	418 345	418 756	0,10	449 361	449 773	0,09
2000	404 646	405 009	0,09	427 558	427 922	0,09
2001	428 295	428 637	0,08	445 653	445 995	0,08
2002	415 998	416 238	0,06	430 799	431 040	0,06
2003	418 802	419 064	0,06	440 055	440 318	0,06
2004	433 181	433 552	0,09	442 754	443 125	0,08
2005	432 984	433 462	0,11	441 930	442 409	0,11
2006	447 568	448 044	0,11	459 566	460 043	0,10
2007	448 862	449 352	0,11	462 933	463 423	0,11
2008	451 564	451 998	0,10	450 718	451 152	0,10
2009	385 525	385 791	0,07	390 273	390 539	0,07
2010	398 107	398 355	0,06	407 103	407 352	0,06
2011	436 969	437 415	0,10	428 359	428 805	0,10
2012	422 406	422 870	0,11	417 374	417 838	0,11
2013	427 975	428 237	0,06	408 988	409 250	0,06
2014	382 638	382 854	0,06	362 562	362 778	0,06
2015	338 850	338 925	0,02	319 108	319 183	0,02
2016	361 765	361 982	0,06	337 413	337 630	0,06
2017	337 935	336 734	-0,36	322 999	323 295	0,09
2018	366 878	364 738	-0,58	339 500	339 822	0,09
2019	359 153	357 451	-0,47	333 835	334 119	0,09
2020	315 941	317 636	0,54	317 696	318 039	0,11

In IPPU sector recalculations were performed in: 2.A.1 Cement production CO_2 and SO_2 emissions for 2015 - 2020 was made due to adjustment of the data of cement and clinker production and the data of non-carbonate raw material components use and CaO and MgO content respectively according to the data obtained from enterprises; 2.A.3 Glass Production CO_2 emissions for 1990-2020 was made due to adjustment of the data of soda ash content in furnace charge in glass production according to the data obtained from enterprises, as well as CO_2 and NMVOC emissions in 2020 due to correction of the data of glass production according to the data obtained from SSSU; 2.A.4.a Ceramics Production CO_2 emissions for 2015 - 2020 was made due to adjustment of the data of ceramics production according to the data obtained from enterprises; 2.A.4.b Other Uses of Soda Ash of CO_2 emissions for 1990-2020 was made due to adjustment of the data of soda ash content in furnace charge in glass production which are included in category 2.A.3 Glass Production and excluded from this category according to the data obtained from enterprises; 2.B.1 Ammonia Production of CO_2 emissions for 1990-2020 was carried out due to the change in the data source of urea production (from the data of SSSU to data received from enterprises), to provide a higher level of data for the Tier 3 for calculation in this category; 2.C.1 Iron and Steel production of CO_2 and NMVOC emissions for 2019 – 2020 was made due to correction of the pellets production according to the data obtained from enterprises-producers; 2.C.2 Ferroalloys production of CO_2 emissions for 2019 -2020 was made due to adjustment of the data of raw materials consumption for ferroalloys production according to the data obtained from enterprises; 2.D.2 Paraffin Wax Use of CO_2 emissions for 2020 was made due to adjustment of the data of paraffin waxes use in accordace with data obtained from SSSU; 2.D.3.b.3 Chemical Products: Production and Processing of NMVOC emissions for 2017 - 2020 was made due to adjustment of the data of chemical fibers and threads in accordace with data obtained from SSSU; 2.F.1.c Commercial refrigeration HFC-125 emissions for the 2020 was made due to correction of the mechanical misprint occurred by entering data of import of HFC and HFC-containing equipment for industrial refrigeration systems; 2.F.2 Foam Blowing Agents of HFC emissions in 2011 - 2020 was made due to accounting of the HFC-152a emissions that were calculated for the first time in accordance with 2006 IPCC Guide-lines [1] and data obtained from State Custom Service of Ukraine; 2.F.3 Fire protection of HFC emissions in 2018 - 2020 was made due to adjustment of the data of the use of HFCs in equipment production in accordance with data obtained from enterprises 2.G.1 Electrical Equipment of SF6 emissions was made due to adjustment of the data of the amounts of SF6 in installed gas-insulated equipment for 2019 - 2020 according to the data obtained from enterprises; 2.G.3 N_2O from Product Uses of N_2O emissions was made due to adjustment of the data of number of surgical operations in 2020 according to the data obtained from enterprise; 2.H.2 Food and Beverages Industry of NMVOC emissions for 1990-2020 was carried out due to the adjustment of the amounts of food and beverages production according to the data obtained from SSSU.

During the NIR preparation recalculations in Agriculture sector have occurred in 3.A Enteric fermentation, 3.B Manure management and 3.D Agricultural soils categories (see Chapters 5.2.5, 5.3.5 and 5.5.5). There are several reasons for recalculations in these categories:

- camels, mules and asses livestock clarification for 2017-2020;
- clarification of cattle livestock for 2020.

Emissions recalculation led to its changes for entire time series (the smallest – $2{,}80\times10^{-6}$ % in 2017, the largest –$1{,}14\times10^{-4}$% in 2018).

In the LULUCF sector the main recalculations were performed in:

1) Forest land due to: revision of activity data for the forest fires that resulted in recalculations for 2018-2020;
2) Cropland and Grasslands due to: recalculations in Manure Management category, which affected the amount of manure be applied to soils in 2017-2020;
3) HWP due to data clarification by FAO for 2017-2020.

In Waste sector recalculations were made in 5.A. "Solid Waste Disposal" and 5.C.1 "Waste incineration" sub-categories for 2020 due to the clarification of data. As a result of the recalculation, emissions decreased by 0.2-0.3 %. In the category 5.D.1 "Domestic Wastewater", recalculations were carried out due to clarification of data for 2016, 2019, 2020. As a result of recalculations, emissions increased by 0.01-0,1 %. In the category 5.D.2 "Industrial Wastewater", recalculations were made due to clarification and taking into account additional data on the release of certain type of products P_(i) for each industry for the entire time series. As a result of recalculations, methane emissions increased by 0.5-38.8 % and nitrous oxide emissions – by 4.5-27.4 %.

11 INFORMATION ON CHANGES IN THE NATIONAL GHG INVENTORY SYSTEM

There were no changes in the National GHG Inventory System arrangements since the last submission of Ukraine.

12 AUTHORS

The National Inventory Report was developed with the participation of:

Name	Place of work, position	The area of responsibility
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Oleksandr Tymoshchuk	BI «NCI», Deputy head of the Greenhouse Gas Inventory Department, Head of Department of Greenhouse Gas Inventory in the Agriculture and Forestry fields and Waste management, Candidate of Agricultural Sciences	Sector Agriculture
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For development of individual chapters of the NIR following organizations were participating:

1. Ukrainian state forest inventory production association «Ukrderzhlisproekt»;
2. Public Organization «Bureau of complex analysis and forecasts «BIAF»;
3. Institute of Animal Science of NAASU;
4. Ukrainian Hydrometeorological Institute.

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ANNEX 1 KEY CATEGORIES

Identification of key categories makes possible to identify the categories that require more detailed study, which allows to comprehensively use available resources. Their determination was performed using the methods described in the 2006 IPCC Guidelines. Detailed categories specialization, that reported in Table A1.1, used for key categories estimation according to 2006 IPCC Guidelines methodology.

Results of the analysis of key categories in base year and last reported year are shown in Tables A1.2 – A1.7. The analysis was based on Tier 1 approach and included emission analysis for base year (Tables A1.2 – A1.3), and analysis of emission trends for report year (Tables A1.4 – A1.7). It should be noted that the emission level and trend analysis was performed in two steps. At the first step of the analysis, key categories were defined not taking into account the LULUCF sector in the general list of categories. The second step took into account categories of the LULUCF sector. After that, the categories that were included into key categories at the first step but were "pushed out" in the second step were included into the final list of key categories.

Table A1.1. Category specialization for key categories estimation

IPCC source category		Gas
1.A.1	Fuel combustion - Energy industries - Liquid fuels	CO_2
1.A.1	Fuel combustion - Energy industries - Liquid fuels	CH_4
1.A.1	Fuel combustion - Energy industries - Liquid fuels	N_2O
1.A.1	Fuel combustion - Energy industries - Solid fuels	CO_2
1.A.1	Fuel combustion - Energy industries - Solid fuels	CH_4
1.A.1	Fuel combustion - Energy industries - Solid fuels	N_2O
1.A.1	Fuel combustion - Energy industries - Gaseous fuels	CO_2
1.A.1	Fuel combustion - Energy industries - Gaseous fuels	CH_4
1.A.1	Fuel combustion - Energy industries - Gaseous fuels	N_2O
1.A.1	Fuel combustion - Energy industries - Other fossil fuels	CO_2
1.A.1	Fuel combustion - Energy industries - Other fossil fuels	CH_4
1.A.1	Fuel combustion - Energy industries - Other fossil fuels	N_2O
1.A.1	Fuel combustion - Energy industries - Peat	CO_2
1.A.1	Fuel combustion - Energy industries - Peat	CH_4
1.A.1	Fuel combustion - Energy industries - Peat	N_2O
1.A.1	Fuel combustion - Energy industries - Biomass	CH_4
1.A.1	Fuel combustion - Energy industries - Biomass	N_2O
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid fuels	CO_2
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid fuels	CH_4
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid fuels	N_2O
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid fuels	CO_2
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid fuels	CH_4
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid fuels	N_2O
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous fuels	CO_2
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous fuels	CH_4
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous fuels	N_2O
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other fossil fuels	CO_2
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other fossil fuels	CH_4
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other fossil fuels	N_2O
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO_2
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH_4
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N_2O
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH_4
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N_2O
1.A.3.a	Civil Aviation	CO_2
1.A.3.a	Civil Aviation	CH_4
1.A.3.a	Civil Aviation	N_2O
1.A.3.b	Road Transportation	CO_2
1.A.3.b	Road Transportation	CH_4
1.A.3.b	Road Transportation	N_2O

IPCC source category		Gas
1.A.3.c	Railway Transport	CO_2
1.A.3.c	Railway Transport	CH_4
1.A.3.c	Railway Transport	N_2O
1.A.3.d	Water transport - Liquid fuels	CO_2
1.A.3.d	Water transport - Liquid fuels	CH_4
1.A.3.d	Water transport - Liquid fuels	N_2O
1.A.3.e	Other types of transport	CO_2
1.A.3.e	Other types of transport	CH_4
1.A.3.e	Other types of transport	N_2O
1.A.4	Other sectors - Liquid fuels	CO_2
1.A.4	Other sectors - Liquid fuels	CH_4
1.A.4	Other sectors - Liquid fuels	N_2O
1.A.4	Other sectors - Solid fuels	CO_2
1.A.4	Other sectors - Solid fuels	CH_4
1.A.4	Other sectors - Solid fuels	N_2O
1.A.4	Other sectors - Gaseous fuels	CO_2
1.A.4	Other sectors - Gaseous fuels	CH_4
1.A.4	Other sectors - Gaseous fuels	N_2O
1.A.4	Other sectors - Other Fossil Fuels	CO_2
1.A.4	Other sectors - Other Fossil Fuels	CH_4
1.A.4	Other sectors - Other Fossil Fuels	N_2O
1.A.4	Other Sectors - Peat	CO_2
1.A.4	Other Sectors - Peat	CH_4
1.A.4	Other Sectors - Peat	N_2O
1.A.4	Other Sectors - Biomass	CH_4
1.A.4	Other Sectors - Biomass	N_2O
1.A.5	Unspecified categories - Liquid fuels	CO_2
1.A.5	Unspecified categories - Liquid fuels	CH_4
1.A.5	Unspecified categories - Liquid fuels	N_2O
1.B.1	Fugitive emissions from Solid fuels	CO_2
1.B.1	Fugitive emissions from Solid fuels	CH_4
1.B.2.a	Fugitive emissions from Oil and natural gas - Oil	CO_2
1.B.2.a	Fugitive emissions from Oil and natural gas - Oil	CH_4
1.B.2.b	Fugitive emissions from Oil and natural gas - Natural gas	CO_2
1.B.2.b	Fugitive emissions from Oil and natural gas - Natural gas	CH_4
1.B.2.c	Fugitive emissions from Oil and natural gas - Ventilation and flaring	CO_2
1.B.2.c	Fugitive emissions from Oil and natural gas - Ventilation and flaring	CH_4
1.B.2.c	Fugitive emissions from Oil and natural gas - Ventilation and flaring	N_2O
2.A.1	Cement Production	CO_2
2.A.2	Lime Production	CO_2
2.A.3	Glass Production	CO_2
2.A.4	Other processes using carbonates	CO_2
2.B.1	Ammonia Production	CO_2
2.B.2	Nitric Acid Production	N_2O
2.B.3	Adipic Acid Production	N_2O
2.B.4	Production of Caprolactam, Glyoxal, and Glyoxylic Acid	N_2O
2.B.5	Carbide Production	CO_2
2.B.5	Carbide Production	CH_4
2.B.6	Titanium Dioxide Production	CO_2
2.B.7	Soda Ash Production	CO_2
2.B.8	Petrochemical and Carbon Black Production	CO_2
2.B.8	Petrochemical and Carbon Black Production	CH_4
2.C.1	Iron and Steel production	CO_2
2.C.1	Iron and Steel production	CH_4
2.C.2	Ferroalloys Production	CO_2
2.C.2	Ferroalloys Production	CH_4
2.C.5	Lead production	CO_2
2.C.6	Zinc production	CO_2
2.D.1	Lubricant use	CO_2

IPCC source category		Gas
2.D.2	Paraffin Wax use	CO_2
2.F.1	Refrigeration and Air Conditioning Systems	HFC
2.F.2	Foam Blowing Agents	HFC
2.F.3	Fire Extinguishers/Gas Fire Extinguishing Systems	HFC
2.F.4	Aerosols	HFC
2.F.5	Solvents	HFC
2.G	Other Production and Use	SF_6
2.G	Other Production and Use	N_2O
3.A	Enteric fermentation	CH_4
3.B	Manure management	CH_4
3.B	Manure management	N_2O
3.C	Rice Cultivation	CH_4
3.D.1	Direct N_2O emissions from managed soils	N_2O
3.D.2	Indirect N_2O Emissions from managed soils	N_2O
3.G	Liming	CO_2
3.H	Urea Application	CO_2
4.A.1	Forest Land remaining Forest Land	CO_2
4.A.2	Land converted to Forest Land	CO_2
4.B.1	Cropland remaining Cropland	CO_2
4.B.2	Land Converted to Cropland	CO_2
4.C.1	Grassland remaining Grassland	CO_2
4.C.2	Land Converted to Grassland	CO_2
4.D.1.1	Peat Extraction remaining Peat Extraction	CO_2
4.D.2	Land Converted to Wetlands	CO_2
4.E.2	Land Converted to Settlements	CO_2
4.F.2	Land Converted to Other Land	CO_2
4.G	Harvested Wood Products (HWP)	CO_2
4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	N_2O
4(III)	Direct N_2O emissions from nitrogen mineralization/immobilization	N_2O
4(V)	Biomass Burning	CH_4
4(V)	Biomass Burning	CO_2
4(V)	Biomass Burning	N_2O
5.A	Solid Waste disposal	CH_4
5.B	Biological Treatment of Solid Waste	CH_4
5.B	Biological Treatment of Solid Waste	N_2O
5.C	Incineration and open burning of waste	CO_2
5.C	Incineration and open burning of waste	CH_4
5.C	Incineration and open burning of waste	N_2O
5.D	Wastewater Treatment and Discharge	CH_4
5.D	Wastewater Treatment and Discharge	N_2O

Table A1.2 Key categories analysis by level, excluding LULUCF, in 1990

IPCC source category	Gas	Emissions, kt CO_2-eq.	Share in total emissions	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	121 545.98	0.129	0.13
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	96 756.68	0.103	0.23
2.C.1 Iron and Steel Production	CO_2	79 689.74	0.085	0.32
1.B.1 Fugitive emissions from Solid Fuels	CH_4	61 923.39	0.066	0.38
1.A.3.b Road Transportation	CO_2	59 916.59	0.064	0.45
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	58 071.11	0.062	0.51
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	53 148.53	0.056	0.56
1.A.4 Other Sectors - Solid Fuels	CO_2	48 177.92	0.051	0.61
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	48 058.63	0.051	0.67
1.A.3.e Other Transportation	CO_2	39 807.94	0.042	0.71
3.A Enteric Fermentation	CH_4	39 311.34	0.042	0.75
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	33 008.26	0.035	0.78
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	29 955.80	0.032	0.82
3.D.1 Direct N2O Emissions From Managed Soils	N_2O	29 655.98	0.031	0.85
1.A.4 Other Sectors - Gaseous Fuels	CO_2	26 458.72	0.028	0.88
1.A.4 Other Sectors - Liquid Fuels	CO_2	23 334.88	0.025	0.90
2.B.1 Ammonia Production	CO_2	9 798.96	0.010	0.91
2.A.1 Cement Production	CO_2	9 400.94	0.010	0.92
3.D.2 Indirect N2O Emissions From Managed Soils	N_2O	8 022.20	0.009	0.93
5.A Solid Waste Disposal	CH_4	6 534.85	0.007	0.94
2.B.2 Nitric Acid Production	N_2O	5 284.58	0.006	0.94
2.A.2 Lime Production	CO_2	5 121.81	0.005	0.95
5.D Wastewater Treatment and Discharge	CH_4	4 142.58	0.004	0.95
Other				1,00

Table A1.3 Key categories analysis by level, including LULUCF, in 1990

IPCC source category	Gas	Emissions, kt CO_2-eq.	Share in total emissions	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	121 545.98	0.121	0.12
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	96 756.68	0.097	0.22
2.C.1 Iron and Steel Production	CO_2	79 689.74	0.080	0.30
1.B.1 Fugitive emissions from Solid Fuels	CH_4	61 923.39	0.062	0.36
1.A.3.b Road Transportation	CO_2	59 916.59	0.060	0.42
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	58 071.11	0.058	0.48
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	53 148.53	0.053	0.53
1.A.4 Other Sectors - Solid Fuels	CO_2	48 177.92	0.048	0.58
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	48 058.63	0.048	0.63
1.A.3.e Other Transportation	CO_2	39 807.94	0.040	0.67
3.A Enteric Fermentation	CH_4	39 311.34	0.039	0.71
4.A.1 Forest Land Remaining Forest Land	CO_2	-37 650.71	0.038	0.74
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	33 008.26	0.033	0.78
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	29 955.80	0.030	0.81
3.D.1 Direct N2O Emissions From Managed Soils	N_2O	29 655.98	0.030	0.84
1.A.4 Other Sectors - Gaseous Fuels	CO_2	26 458.72	0.026	0.86
1.A.4 Other Sectors - Liquid Fuels	CO_2	23 334.88	0.023	0.88
4.D.1.1 Peat Extraction Remaining Peat Extraction	CO_2	12 207.91	0.012	0.90
2.B.1 Ammonia Production	CO_2	9 798.96	0.010	0.91
2.A.1 Cement Production	CO_2	9 400.94	0.009	0.92
3.D.2 Indirect N2O Emissions From Managed Soils	N_2O	8 022.20	0.008	0.92
5.A Solid Waste Disposal	CH_4	6 534.85	0.007	0.93
2.B.2 Nitric Acid Production	N_2O	5 284.58	0.005	0.94
2.A.2 Lime Production	CO_2	5 121.81	0.005	0.94
4.B.1 Cropland Remaining Cropland	CO_2	-4 561.21	0.005	0.95
5.D Wastewater Treatment and Discharge	CH_4	4 142.58	0.004	0.95
1.B.2.a Fugitive Emissions from Oil and Natural Gas - Oil	CH_4	3 883.15	0.004	0.95
Other				1,00

Table A1.4. Key categories analysis by level, excluding LULUCF, in 2021

IPCC source category	Gas	Emissions, kt CO_2-eq.	Share in total emissions	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	53 395.01	0.162	0.16
2.C.1 Iron and Steel Production	CO_2	39 901.70	0.121	0.28
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	35 548.35	0.108	0.39
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	29 790.08	0.090	0.48
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	26 645.41	0.081	0.56
1.A.3.b Road Transportation	CO_2	24 351.21	0.074	0.63
1.A.4 Other Sectors - Gaseous Fuels	CO_2	17 849.86	0.054	0.69
1.B.1 Fugitive emissions from Solid Fuels	CH_4	10 968.41	0.033	0.72
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10 449.53	0.032	0.75
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	9 713.26	0.029	0.78
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	7 784.96	0.024	0.81
5.A Solid Waste Disposal	CH_4	7 699.52	0.023	0.83
1.A.3.e Other Transportation	CO_2	7 339.53	0.022	0.85
3.A Enteric Fermentation	CH_4	7 047.92	0.021	0.87
2.A.1 Cement Production	CO_2	4 338.54	0.013	0.89
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	3 703.24	0.011	0.90
2.B.1 Ammonia Production	CO_2	3 435.27	0.010	0.91
5.D Wastewater Treatment and Discharge	CH_4	3 366.83	0.010	0.92
2.B.8 Petrochemical and Carbon Black Production	CH_4	3 355.52	0.010	0.93
2.B.2 Nitric Acid Production	N_2O	2 407.09	0.007	0.94
2.A.2 Lime Production	CO_2	2 353.13	0.007	0.94
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CO_2	1 717.39	0.005	0.95
2.C.2 Ferroalloys Production	CO_2	1 606.13	0.005	0.95
Other				1,00

Table A1.5 Key categories analysis by level, including LULUCF, in 2021

IPCC source category	Gas	Emissions, kt CO_2-eq.	Share in total emissions	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	53 395.01	0.128	0.13
4.B.1 Cropland Remaining Cropland	CO_2	48 497.97	0.116	0.24
2.C.1 Iron and Steel Production	CO_2	39 901.70	0.096	0.34
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	35 548.35	0.085	0.42
4.A.1 Forest Land Remaining Forest Land	CO_2	-31 611.86	0.076	0.50
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	29 790.08	0.071	0.57
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	26 645.41	0.064	0.64
1.A.3.b Road Transportation	CO_2	24 351.21	0.058	0.69
1.A.4 Other Sectors - Gaseous Fuels	CO_2	17 849.86	0.043	0.74
1.B.1 Fugitive emissions from Solid Fuels	CH_4	10 968.41	0.026	0.76
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10 449.53	0.025	0.79
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	9 713.26	0.023	0.81
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	7 784.96	0.019	0.83
5.A Solid Waste Disposal	CH_4	7 699.52	0.018	0.85
1.A.3.e Other Transportation	CO_2	7 339.53	0.018	0.87
3.A Enteric Fermentation	CH_4	7 047.92	0.017	0.88
2.A.1 Cement Production	CO_2	4 338.54	0.010	0.89
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	3 703.24	0.009	0.90
2.B.1 Ammonia Production	CO_2	3 435.27	0.008	0.91
5.D Wastewater Treatment and Discharge	CH_4	3 366.83	0.008	0.92
2.B.8 Petrochemical and Carbon Black Production	CH_4	3 355.52	0.008	0.93
4.G Harvested Wood Products	CO_2	-3 163.81	0.008	0.93
2.B.2 Nitric Acid Production	N_2O	2 407.09	0.006	0.94
2.A.2 Lime Production	CO_2	2 353.13	0.006	0.95
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CO_2	1 717.39	0.004	0.95
2.C.2 Ferroalloys Production	CO_2	1 606.13	0.004	0.95
Other				1,00

Table A1.6. Key categories analysis by trend, excluding LULUCF, in 2021

IPCC source category	Gas	Emissions, kt CO_2-eq.	Share in total emissions	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	53395.01	0.092	0.09
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	29790.08	0.092	0.18
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	936.48	0.084	0.27
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	26645.41	0.076	0.34
1.A.4 Other Sectors - Solid Fuels	CO_2	979.42	0.076	0.42
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	35548.35	0.072	0.49
2.C.1 Iron and Steel Production	CO_2	39901.70	0.057	0.55
1.B.1 Fugitive emissions from Solid Fuels	CH_4	10968.41	0.051	0.60
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	427.78	0.048	0.65
1.A.4 Other Sectors - Gaseous Fuels	CO_2	17849.86	0.041	0.69
1.A.4 Other Sectors - Liquid Fuels	CO_2	88.10	0.038	0.73
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	9713.26	0.034	0.76
3.A Enteric Fermentation	CH_4	7047.92	0.032	0.79
1.A.3.e Other Transportation	CO_2	7339.53	0.031	0.82
5.A Solid Waste Disposal	CH_4	7699.52	0.026	0.85
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	7784.96	0.024	0.87
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	3703.24	0.018	0.89
1.A.3.b Road Transportation	CO_2	24351.21	0.016	0.91
2.B.8 Petrochemical and Carbon Black Production	CH_4	3355.52	0.016	0.92
5.D Wastewater Treatment and Discharge	CH_4	3366.83	0.009	0.93
2.F.1 Refrigeration and Air conditioning	HFC	1528.99	0.007	0.94
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10449.53	0.005	0.94
1.A.3.d Domestic Navigation - Liquid Fuels	CO_2	82.33	0.005	0.95
2.A.1 Cement Production	CO_2	4338.54	0.005	0.95
Other				1,00

Table A1.7. Key categories analysis by trend, including LULUCF, in 2021

IPCC source category	Gas	Emissions, kt CO_2-eq.	Share in total emissions	Cumulative total of Column D
A	B	C	D	E
4.B.1 Cropland Remaining Cropland	CO_2	48497.97	0.174	0.17
4.A.1 Forest Land Remaining Forest Land	CO_2	-31611.86	0.086	0.26
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	26645.41	0.082	0.34
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	936.48	0.069	0.41
1.A.4 Other Sectors - Solid Fuels	CO_2	979.42	0.063	0.47
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	29790.08	0.053	0.53
1.B.1 Fugitive emissions from Solid Fuels	CH_4	10968.41	0.050	0.58
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	427.78	0.039	0.62
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	53395.01	0.036	0.65
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	9713.26	0.035	0.69
1.B.2.b Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH_4	35548.35	0.032	0.72
1.A.4 Other Sectors - Liquid Fuels	CO_2	88.10	0.031	0.75
3.A Enteric Fermentation	CH_4	7047.92	0.031	0.78
1.A.3.e Other Transportation	CO_2	7339.53	0.031	0.81
1.A.4 Other Sectors - Gaseous Fuels	CO_2	17849.86	0.020	0.83
2.C.1 Iron and Steel Production	CO_2	39901.70	0.016	0.85
4.D.1.1 Peat Extraction Remaining Peat Extraction	CO_2	232.98	0.016	0.87
5.A Solid Waste Disposal	CH_4	7699.52	0.015	0.88
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	7784.96	0.013	0.89
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10449.53	0.012	0.91
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	3703.24	0.012	0.92
2.B.8 Petrochemical and Carbon Black Production	CH_4	3355.52	0.010	0.93
1.A.3.b Road Transportation	CO_2	24351.21	0.005	0.93
5.D Wastewater Treatment and Discharge	CH_4	3366.83	0.005	0.94
4.E.2 Land Converted to Settlements	CO_2	1567.48	0.005	0.94
2.F.1 Refrigeration and Air conditioning	HFC	1528.99	0.005	0.95
4.C.1 Grassland Remaining Grassland	CO_2	196.09	0.005	0.95
Other				1,00

ANNEX 2 METHODOLOGY FOR EMISSION ASSESSMENT IN THE ENERGY SECTOR

A2.1 The method to determine GHG emissions from stationary fuel combustion

When conducting the national inventory of GHG emissions from combustion of fossil fuels in the period of 1990-2021, the methodology of 2006 IPCC Tier 1 and Tier 2 was applied (in a few exceptional cases - of Tier 3, see below), in accordance with which the amount of a certain type of GHG emissions for a particular CRF category at burning of a specific type of fuel is estimated under expression A1:

$$B_{gfi} = FC_{fi} \bullet KB_{gfi} \qquad \text{(A1)}$$

where:

B_{gfi}	—	The amount of emissions of a particular type of GHG (index *g, g=1÷G)* at burning of a particular type of fuel, which corresponds to the index *f, f=1÷F* in the emission source category under the CRF corresponding to index *i, i=1÷I,* (kg);
FC_{fi}	—	The amount of fuel burned *f* in the *i* emission source category in accordance with the CRF (TJ);
KB_{gfi}	—	The default ratio of GHG emissions or the national coefficient at combustion (kg of GHG/TJ). This factor for CO_2 takes into account carbon content in fuel and its degree of oxidation.

The total amount of emissions B_g under the *i* emission source category for individual types of GHGs is determined as follows:

$$B_{gi} = \sum_{f=1}^{F} B_{gfi} \qquad \text{(A2)}$$

The total amount of emissions B_i under the *i* emission source category for all types of GHGs is determined as follows:

$$B_i = \sum_{g=1}^{G} B_{gi} \qquad \text{(A3)}$$

The methodology for calculating emissions in category 1.A.3.a. "Domestic Aviation" is characterized by a number of significant peculiarities and is presented in A2.7.

The key sources of information are the fuel and energy balance (FEB) of the Ukrainian SSR for 1990 [3], statistical reporting forms No. 4-MTP "Report on fuel use and stocks" for years 1991-2020 and No. 11-MTP "Report on results of fuel, heat, and electricity consumption" for years 1991-2015. Since the martial law was introduced in Ukraine in 2022, the statistical reporting form No. 4-MTP was not developed, so determination of GHG emissions from stationary fuel combustion was performed by surrogate method on the basis of the statistical reporting form No. 4-MTP for 2020 and information available from public sources and date from manufacturing enterprises.

A2.2 Sources of activity data

A2.2.1 Statistical reporting form No. 4-MTP "Report on fuel use and stocks"

Form No. 4-MTP is the main form used for inventory of emissions from fossil fuel combustion.

In this form in accordance with the type of economic activity (TEA) of the consumer all fuel and lubricants consumed as well as their losses are attributed to this TEA. At the same time, consumers submit information on use of fuel in accordance with the actual field of its use based on the Classification of Economic Activities, which is reflected in this form. This necessitates application of special methods for proper ensuring of consistency between volumes of fuel used from form No. 4-

MTP and emission categories in accordance with the CRF, because emission factors for some types of GHG may significantly differ for the various categories of emission sources.

Also the structure of form No. 4-MTP requires additional calculations to correctly distribute emission sources. This form is used for reporting by all enterprises regardless of their form of ownership. When submitting information to state statistics authorities, each enterprise specifies the key economic activity in accordance with the National Classification of Economic Activities (NCEA) of the SSSU.

In the period of 1991-2020, this reporting form changed frequently.

In 1991, the form for each sector of the economy contained information on the total consumption by fuel type with separate indication of volume used for household needs.

In the period of 1992-1996, the following information was tracked by each sector of the economy:

1. Total.
2. For conversion - production of electricity and heat.
3. As a raw material.
4. Directly as fuel, separately indicating fuel for household needs and that sold to the public.

In the period 1997-2015, the structure of form No. 4-MTP stabilized. In 2016 it changed significantly, particularly fuel codes (see Table A2.1) and section structure. At present, it consists of four sections, each of them containing information about the specific domain of use of fuel and energy resources. Each section of form No. 4-MTP consists of a table, which horizontally indicates the name of fuel, and in columns - the domain where it was used.

When estimating emissions by using the sector approach, data of the second, third and forth sections are applied.

Section 2 of the form No. 4-MTP contains information on fuel consumption by the energy sector in the following domains:

- field 1 is the sum of fields 2-13, as described below;
- field 2 - fuel consumption for production of hard coal, lignite and peat briquettes;
- field 3 - fuel consumption for production of wood briquettes and charcoal;
- field 4 - fuel consumption for production of coke and coke gas;
- field 5 - fuel consumption for production of various types of gas;
- field 6 - fuel consumption for production of blast furnace coke;
- field 7 - fuel consumption for production of oil products;
- field 8 - fuel consumption for production of heat and electricity at common use power plants;
- field 9 - fuel consumption for production of heat and electricity at power plants of enterprises;
- field 10 - fuel consumption for production of heat and electricity at common use combined heat and power plants (CHPs);
- field 11 - fuel consumption for production of heat and electricity at CHPs of enterprises;
- field 12 - fuel consumption for production of heat at heat power stations and boiler plants;
- field 13 - fuel consumption for production of heat and electricity by other enterprises and plants;
- field 14 - fuel consumption for own use of power plants and enterprises.

Section 3 of form No. 4-MTP contains information on final fuel consumption in the following domains:

- field 1 - fuel consumption for non-energy purposes;
- field 2 – final fuel consumption;
- field 3 - fuel consumption by in-house factory transport;
- field 4 - fuel consumption by international marine and avia transport;
- field 5 – fuel sold to the public.

Section 4 of form No. 4-MTP contains information on fuel losses at its transportation, distribution, storage etc.

A2.2.2 Statistical reporting form No. 11-MTP "Report on results of fuel, heat, and electricity consumption"

Form No.11-MTP section 1 "Fuel" and the Annex (form No.11-MTP (fuel)) "Actual fuel consumption for production of certain types of products and work" with respect to oil refining are used for inventory purposes.

From section 1 data on volumes of oil refining are used, and from the annex 11-MTP (fuel) - the volume of fuel used for these purposes.

In 2016 and further the structure of form No. 11-MTP was changed significantly and ceased to contain data on fuel consumption.

A2.2.3 Fuel and energy balances of Ukraine

The FEB of Ukraine for 1990 was used to calculate GHG emissions from fuel combustion within emission inventory. It contains all the necessary detailed information on fuel consumption, except for data on fuel consumption for oil refining, which are accounted for in other industries and are not explicitly indicated.

FEBs developed by the SSSU and the IEA in the next years cannot be properly applied for the purpose of GHG inventory, because they do not contain details necessary for calculations according to IPCC guidelines.

A2.3 Fuel structure

The range of fuels in the national statistics differs from the range defined by [1], and, as noted, it has undergone a lot of changes. Fuel structure is shown in the table A2.1.

Table A2.1. Types of fuels used

#	Fuel	Groups of fuels*	Fuel code	
			2015	2016 - 2021
1	Hard coal	S	100	110
2	Briquettes, pellets from hard coal	S	110	140
3	Brown coal	S	115	120
4	Briquettes, pellets from brown coal	S	120	150
5	Non-agglomerated fuel peat	P	130	130
6	Briquettes, pellets from peat	P	140	160
7	Crude oil, including oil from bituminous materials	L	150	410
8	Gas condensate	L	160	415
9	Natural gas	G	170	310
10	Charcoal	B	185	720
11	Firewood	B	190	740
12	Fuel briquettes and pellets from wood and other natural materials	B	195	730
13	Biodiesel from oils, sugar and starch crops, and animal fats	B	198	782
14	Other types of source fuels	B	200	750,760,770,790
15	Coke and semi-coke from hard coal, gaseous coke	S	220	170
16	Hard, brown coal, and peat tars	S	225	200
17	Pitch and pitch coke	S	226	190
18	Aviation gasoline	L	230	450
19	Motor gasoline	L	240	430
20	Mixed motor fuel containing bio-ethanol ... 5-30%	B	245	435
21	Fuel for jet engines of the gasoline type	L	250	460
22	Oil distillates, other light fractions	L	260	510
23	Fuel for jet engines of the kerosene type	L	270	470
24	Kerosene	L	280	480

#	Fuel	Groups of fuels*	Fuel code	
			2015	2016 - 2021
25	Gas oils	L	300	440
26	Medium oil distillates, other medium fractions	L	310	520
27	Heavy fuel black oils	L	320	490
28	Petroleum oils, heavy oil distillates	L	330	530
29	Propane and butane, liquefied	L	430	540
30	Ethylene, propylene...	L	440	580
31	Petroleum coke (including shale)	L	460	570
32	Other types of oil products	L	500	650
33	Other fuel processing products	Oth	630	800
34	Coke oven gas produced as a byproduct	S	600	220

** S - solid fuel, L - liquid fuels, G - gaseous fuel, B – biomass, P – peat, Oth. – others*

A2.4 Methods to determine the fuel combustion volume by CRF categories

A2.4.1 Stationary fuel combustion

When calculating the volume of GHG emissions at stationary combustion, motor fuels in CRF category 1.A.1 “Energy Industries” were not transferred to other sources of emissions; in categories 1.A.2 “Manufacturing Industries and Construction” and 1.A.4 “Other Sectors” motor fuels (gasoline, gas oil, etc., for the exception of liquefied propane and butane) were not accounted for the period of 1991-2021 and were transferred to the category of mobile sources - CRF 1.A.3 “Transport”, because no information is available for the period on their use in stationary combustion. This information is available only for 1990.

Lubricants are accounted for in the IPPU sector as non-energy use. Small amounts of lubricants are accounted for in CRF subcategory 1.A.3.b.iv “Motorcycles”.

Activity data of fuel consumption by CRF category at stationary fuel combustion for 2021 are presented in Table A2.2.

Table A2.2. Activity data of fuel consumption at stationary fuel combustion for 2021 in accordance with CRF categories

CRF category	Determining the volume of fuel burned
1.A.1. Fuel and Energy Industry	
1.A.1.a Public Electricity and Heat Production	
1.A.1.ai Electricity Generation	Form No.4-MTP total, Section 2, Column 8
1.A.1.aii Combined Heat and Power generation (CHP)	Form No.4-MTP total, Section 2, Columns 9,10, 11;
1.A.1.aiii Heat Plants	Form No.4-MTP total, Section 2, Column 12
1.A.1.b Petroleum Refining	Based on IEA
1.A.1.c Manufacture of Solid Fuels and Other Energy Industries	Summary of: 1. Form No.4-MTP total, Section 2, Columns 13,14; 2. Section 3, Column 2 minus Columns 3,4 of the form No.4-MTP for TEA with the codes: - 05 "Production of lignite and hard coal"; - 06 "Oil and Natural Gas"
1.A.2. Manufacturing Industries and Construction	
1.A.2.a Iron and Steel	Form No.4-MTP kved, TEA Division 24 "Metallurgical Industry", Section 3, Column 2 minus Columns 3,4; Minus: fuel consumed under form No.4-MTP kved, TEA Division 24.4 "Production of precious and other non-ferrous metals"
1.A.2.b Non-Ferrous Metals	Form No.4-MTP kved, TEA Division 24.4 "Production of precious and other non-ferrous metals", Section 3, Column 2 minus Columns 3,4
1.A.2.c Chemicals	Form No.4-MTP kved, TEA Division 20 "Production of chemical substances and chemical products", Section 3, Column 2 minus Columns 3,4
1.A.2.d Pulp, Paper and Print	Summary of:

CRF category	Determining the volume of fuel burned
	1. Form No.4-MTP kved, TEA Division 17 "Manufacture of paper and paper products", Section 3, Column 2 minus Columns 3,4; 2. Form No.4-MTP kved, TEA Division 18 "Printing and reproduction of information", Section 3, Column 2 minus Columns 3,4
1.A.2.e Food Processing, Beverages and Tobacco	Summary of: 1. Form No.4-MTP kved, TEA Division 10 "Manufacture of food products", Section 3, Column 2 minus Columns 3,4; 2. Form No.4-MTP kved, TEA Division 11 "Manufacture of beverages", Section 3, Column 2 minus Columns 3,4; 3. Form No.4-MTP kved, TEA Division 12 "Manufacture of tobacco products", Section 3, Column 2 minus Columns 3,4
1.A.2.f Non-metallic minerals	Form No.4-MTP kved, TEA Division 23 "Production of other non-ferrous mineral products", Section 3, Column 2 minus Columns 3,4
1.A.2.g Other Industrial Products and Construction	Summary of: 1. Form No.4-MTP kved, TEA Division BCDE "Industry", Section 3, Column 2 minus Columns 3,4; 2. Form No.4-MTP kved, TEA Division F "Construction", Section 3, Column 2 minus Columns 3,4. Minus: 1. Volume of fuel burned in categories 1A2a – 1A2f; 2. The difference between Field 2 and Fields 3,4 of section 3 of form No.4-MTP for TEA with the codes: - 05 "Production of lignite and hard coal"; - 06 "Oil and Natural Gas"
1.A.4. Other Sectors	
1.A.4.a Commercial/Institutional	Summary of: Form No.4-MTP kved, TEA Divisions G,H,I,J,K,L,M,N,O,P,Q,R,S, Section 3, Column 2 minus Columns 3,4
1.A.4.b Residential	Form No.4-MTP total, Section 3, Column 5
1.A.4.c Agriculture/Forestry/Fishing	Summary of: Form No.4-MTP kved, TEA Division A "Agriculture, forests, fishing", Section 3, Column 2 minus Columns 3,4

Given the specific features of form No.4-MTP in 1991, to determine volumes of stationary fuel combustion in accordance with the CRF, expert estimates were used, which were based on data from TEAs for 1990 and those listed in this form.

For the period of 1992 to 1996, the following approach was applied to determine the volume of fuel burned by CRF category - fuel consumption for household needs is attributed to the service sector, and what was sold to the public - to the household sector. Along with this, given the fact that in this period there were active transformation processes in Ukraine's economy, expert opinions were used to smoothen the emission series by CRF categories to some extent to ensure the overall balance of fuel volumes used for power generation [18].

A2.4.2 Mobile fuel combustion

Activity data of fuel consumption by CRF category at mobile fuel combustion for 2021 is presented in Table A2.3.

Table A2.3. Activity data of fuel consumption at mobile fuel combustion for 2021 in accordance with CRF emissions categories

CRF subcategory	Determining the volume of fuel burned	Fuel code
1.A.3.a Domestic Aviation	The fuel volume on aircraft (AC) departures from airports situated in the territory of Ukraine	450 470
1.A.3.b Road Transportation	The fuel volume according to surrogate method (see 3.2.9.2.2)	310 430 440 480 530 540

1.A.3.c Railways	Form No.4-MTP kved, TEA Divisions 49.1, 49.2 "Railway transport", Section 3, Column 2	440
1.A.3.d Domestic Navigation	Form No.4-MTP kved, TEA Division 50, "Waterway transport", Section 3, Column 2	440
1.A.3.e.i Pipeline Transport	The fuel volume provided by enterprises (see 3.2.9.2.5)	310
1.A.3.e.ii Off-Road vehicles and other machinery	The fuel volume according to surrogate method (see 3.2.9.2.5)	310 430 440 530 540

As to biodiesel consumed in categories 1.A.3.b and 1.A.3.e.ii there is no opportunity to collect consumption data for the period 1990-2012. The SSSU began to indicate the amount of biodiesel consumed in statistical forms only in 2013. Taking into account the negligible amount fixed by SSSU in 2013 (222 t), 2014 (0), 2015 (47 t) it is reasonable to suggest that in 1990-2012 the amount of biodiesel consumed was negligible.

A2.5 Emission factors

The method for determination of carbon content in natural gas is presented in A2.6.1, for coal combusted at the TPPs – in A2.6.2, for motor fuels (gasoline, diesel oil and LPG) – in A2.6.3.

For other types of fuels, carbon content factors by default were used in accordance with [1], see details in Table A2.4.

Carbon content factors for CH_4 and N_2O were default ones for the entire time series of 1990-2020 according to [1] within the exception of category 1.A.3.b "Domestic Aviation" for NOx, CO, NMVOC and SO_2 for which determining the CORINAIR 2013 was used.

NCV values for some types of fuel were adopted based on state statistics of Ukraine (forms No. 4-MTP, No. 11-MTP, FEB of the Ukrainian SSR); for some types of fuel the default values were used [1]. Exceptions are hard coal used at TPPs, natural gas, gasoline, diesel oil and LPG for which scientific and analytical activity was performed (see A2.6.1, A2.6.2 and A2.6.3). For details on NCV, see Table A2.4.

Carbon oxidation factors for all the categories within the exception of coal combusted at the TPPs (category 1.A.1.ai, see A.2.6.2) are equal to 1.

The development of CSEFs for petroleum coke and refinery gases are not considered because of small quantity of petroleum coke and including of refinery gases into other oil products by national statistics.

The values of CH_4 and N_2O emission factors are shown in Tables A2.5-A2.8.

Table A2.4. Carbon content factors (t/TJ) and NCV (GJ/t) in different fuels for 2021

Fuel	Code	Carbon content factor	NCV	Fuel	Code	Carbon content factor	NCV
Hard coal	110	25.80*	21.98*	Aviation gasoline	450	19.10	44.30
Briquettes, pellets from hard coal	140	26.60	17.29	Motor gasoline	430	19.65	43.04
Brown coal	120	27.60	8.62	Mixed motor fuel containing bio-ethanol ... 5% -30%	435	19.65	43.04
Briquettes, pellets from brown coal	150	26.60	16.53	Oil distillates, other light fractions	510	19.65	42.50
Non-agglomerated fuel peat	130	28.90	9.44	Fuel for jet engines of the kerosene type	470	19.50	44.10
Briquettes, pellets from peat	160	28.90	14.65	Kerosene	480	19.60	43.08
Crude oil, including oil from bituminous materials	410	20.00	41.55	Gas oil	440	20.12	43.05

Fuel	Code	Carbon content factor	NCV	Fuel	Code	Carbon content factor	NCV
Gas condensate	415	17.50	41.91	Medium oil distillates, other medium fractions	520	20.12	42.50
Natural gas	310	15.21	47.96	Heavy fuel black oils	490	21.10	40.15
Charcoal	720	30.50	27.26	Petroleum oils, heavy oil distillates	530	20,00	39.81
Firewood	740	30.50	11.07	Propane and butane, liquefied	540	17.20	46.01
Fuel briquettes and pellets from wood and other natural materials	730	27.30	11.60	Ethylene, propylene, petroleum gases, other...	580	15.70	43.67
Biodiesel from oils, sugar and starch crops	782	19.30	27.00	Petroleum coke (including shale)	570	26.60	31.65
Other types of source fuels	750,760, 770,790	27.30	11.60	Other types of oil products	650	20.00	40.50
Coke and semi-coke from hard coal, gaseous coke	170	29.20	28.52	Other fuel processing products	800	20.00	40.20
Hard, brown coal, and peat resins	200	22.00	28.00	Coke oven gas produced as a byproduct	220	12.11	35.23
Pitch and pitch coke	190	29.20	28.20				

** - calculated separately for TPPs in A2.6.2*

Table A2.5. Methane emission factors that were applied for estimation of emissions from stationary fuel combustion

Name of the fuel in form No. 4-MTP	Methane emission factors by fuel consumption domains, kg/TJ					
	Code of the fuel in form No. 4-MTP	Energy Industries	Industry and Construction	Agriculture	Commercial/Institutional	Residential Sector
Hard coal	110	1	10	300	10	300
Briquettes, pellets from hard coal	140	1	10	300	10	300
Brown coal	120	1	10	300	10	300
Briquettes, pellets from brown coal	150	1	1	300	10	300
Non-agglomerated fuel peat	130	1	2	300	1	300
Briquettes, pellets from peat	160	1	2	300	1	300
Crude oil, including oil from bituminous materials	410	3	3	10	10	10
Gas condensate	415	3	3	10	10	10
Natural gas	310	1	1	5	5	5
Charcoal	720	200	200	200	200	200
Firewood	740	30	30	300	300	300
Fuel briquettes and pellets from wood and other natural materials	730	30	30	300	300	300
Biodiesel from oils, sugar and starch crops	782	3				
Other types of source fuels	750,760,770,790	30	30	300	300	300
Coke and semi-coke from hard coal, gaseous coke	170	1	1	5	5	5
Hard, brown coal, and peat tars	200	1	10	300	10	300
Pitch and pitch coke	190	1	10	300	10	300
Aviation gasoline	450					
Motor gasoline	430	3				
Motor fuel composite with bioethanol ... 5% -30%	435	3				
Oil distillates, other light fractions	510	3				
Fuel for jet engines of the kerosene type	470					
Kerosene	480	3				
Gas oils	440	3				
Medium oil distillates, other medium fractions	520	3				
Heavy fuel black oils	490	3	3	10	10	10
Petroleum oils, heavy oil distillates	530	3				
Propane and butane, liquefied	540	1	1	5	5	5
Ethylene, propylene, petroleum gases, other...	580	3	3	10	10	10
Petroleum coke	570	3	3	10	10	10
Other types of oil products	650	3	3	10	10	10
Other fuel processing products	800	3	3	10	10	10
Coke oven gas produced as a byproduct	220	1	1	5	5	5

Table A2.6. Nitrous oxide emission factors that were applied for estimation of emissions from stationary fuel combustion

Name of the fuel in form No. 4-MTP	**Methane emission factors by fuel consumption domains, kg/TJ**					
	Code of the fuel in form No. 4-MTP	**Energy Industries**	**Industry and Construction**	**Agriculture**	**Commercial/Institutional**	**Residential Sector**
Hard coal	110	1.5	1.5	1.5	1.5	1.5
Briquettes, pellets from hard coal	140	1.5	1.5	1.5	1.5	1.5
Brown coal	120	1.5	1.5	1.5	1.5	1.5
Briquettes, pellets from brown coal	150	1.5	1.5	1.5	1.5	1.5
Non-agglomerated fuel peat	130	1.5	1.5	1.4	1.4	1.4
Briquettes, pellets from peat	160	1.5	1.5	1.4	1.4	1.4
Crude oil, including oil from bituminous materials	410	0.6	0.6	0.6	0.6	0.6
Gas condensate	415	0.6	0.6	0.6	0.6	0.6
Natural gas	310	0.1	0.1	0.1	0.1	0.1
Charcoal	720	4	4	1	1	1
Firewood	740	4	4	4	4	4
Fuel briquettes and pellets from wood and other natural materials	730	4	4	4	4	4
Biodiesel from oils, sugar and starch crops	782	0.6				
Other types of source fuels	750,760,770,790	4	4	4	4	4
Coke and semi-coke from hard coal, gaseous coke	170	0.1	0.1	0.1	0.1	0.1
Hard, brown coal, and peat tars	200	1.5	1.5	1.5	1.5	1.5
Pitch and pitch coke	190	1.5	1.5	1.5	1.5	1.5
Aviation gasoline	450					
Motor gasoline	430	0.6				
Motor fuel composite with bioethanol ... 5% -30%	435	0.6				
Oil distillates, other light fractions	510	0.6				
Fuel for jet engines of the kerosene type	470					
Kerosene	480	0.6				
Gas oils	440	0.6				
Medium oil distillates, other medium fractions	520	0.6				
Heavy fuel black oils	490	0.6	0.6	0.6	0.6	0.6
Petroleum oils, heavy oil distillates	530	0.6				
Propane and butane, liquefied	540	0.1	0.1	0.1	0.1	0.1
Ethylene, propylene, petroleum gases, other...	580	0.6	0.6	0.6	0.6	0.6
Petroleum coke	570	0.6	0.6	0.6	0.6	0.6
Other types of oil products	650	0.6	0.6	0.6	0.6	0.6
Other fuel processing products	800	0.6	0.6	0.6	0.6	0.6
Coke oven gas produced as a byproduct	220	0.1	0.1	0.1	0.1	0.1

Table A2.7. Methane emission factors that were applied for estimation of emissions from mobile fuel combustion

Name of fuel	Fuel code	1.A.3.a - Civil Aviation	1.A.3.b - Road Transport	1.A.3.c - Railway transport	1.A.3.d - Water transport	1.A.3.e.i - Pipeline transport	1.A.3.e.ii - Off-road transport
	Methane emission factors by fuel consumption domains, kg/TJ						
Natural gas	310					1	
Biodiesel from oils...	782		18.4				115
Aviation gasoline	450	see A2.7					
Motor gasoline	430		18.4				115
Motor fuel composite with bioethanol	435		18.4				115
Aviation gasoline	450	see A2.7					
Oil distillates, other light fractions	510		18.4				115
Jet kerosene-type fuel	470	see A2.7					
Kerosene	480		18.4				115
Gasoil (diesel fuel)	440		3.9	4.15	7		4.15
Oil medium distillates...	520		3.9				4.15
Petroleum oils, heavy oil distillates	530		18.4				4.15
Propane and butane, liquefied	540		92				

Table A2.8. Nitrous oxide emission factors that were applied for estimation of emissions from mobile fuel combustion

Name of fuel	Fuel code	1.A.3.a - Civil Aviation	1.A.3.b - Road Transport	1.A.3.c - Railway transport	1.A.3.d - Water transport	1.A.3.e.i - Pipeline transport	1.A.3.e.ii - Off-road transport
	Nitrous oxide emission factors by fuel consumption domains, kg/TJ						
Natural gas	310					0.1	
Biodiesel from oils...	782		5.6				1.2
Aviation gasoline	450	see A2.7					
Motor gasoline	430		5.6				1.2
Motor fuel composite with bioethanol	435		5.6				1.2
Aviation gasoline	450	see A2.7					
Oil distillates, other light fractions	510		5.6				1.2
Jet kerosene-type fuel	470	see A2.7					
Kerosene	480		5.6				1.2
Gasoil (diesel fuel)	440		3.9	28.6	2		28.6
Oil medium distillates...	520		3.9				28.6
Petroleum oils, heavy oil distillates	530		5.6				28.6
Propane and butane, liquefied	540		3				

A2.6 Determination of physical and chemical parameters of natural gas and power-generating coals

A2.6.1 Natural gas

The input data for determination of parameters of natural gas in the Ukraine gas transportation system are passport certificates of physical and chemical parameters of gas, which contain daily information (from all gas measuring stations and for each pipeline) on the elemental composition of natural gas, calorific value, density, consumption, and other physical and chemical indicators. These passport certificates were provided by the companies NJSC "Naftogaz of Ukraine", PJSC "Ukrgasvydobuvannya", JSC "UA transmission system operator".

The component composition of natural gas is determined based on chromatographic analysis in line with [9], based on which the net calorific value of natural gas is estimated according to [10].

The carbon content in natural gas was determined on the basis of the estimated value of the average percentage of carbon content and calorific value according to the formula:

$$k_c^{Av} = \frac{\sum_i \rho_i^{av} \cdot r_i^{av} \cdot \frac{M_C}{M_i}}{NCV^{av}}; \quad (A4)$$

Where: k_c^{Av} – is the average carbon content in natural gas consumed in the country, t/TJ;
ρ_i^{av} – the average density of the *i* component of natural gas, the molecule of which contains the carbon atom, in relative units;
r_i^{av} – the average volume ratio of the *i* component of natural gas, the molecule of which contains the carbon atom, in relative units;
M_C – the molar weight of carbon, g/mole;
M_i – the molar weight of the *i* component of natural gas, the molecule of which contains the carbon atom, g/mole;
i – the index of the component of natural gas, the molecule of which contains the carbon atom;
NCV^{av} – the average net calorific value of natural gas, TJ/million m$^{3;}$

Average values of density, volume fractions, and the net calorific value of natural gas were calculated as the weighted average of the respective indicators of import and domestic natural gas production in the country.

Detailed data on NCV, carbon content and density are presented in Table A2.9.

Table A2.9. Average physical and chemical parameters of consumed natural gas in Ukraine, 1990-2021

Parameter*	NCV	Carbon content	Density	CH_4	CO_2
Year	GJ/t	tC/TJ	kg/m3	% vol.	% vol.
1990	48.720	15.180	0.697	96.245	0.163
1991	48.720	15.180	0.697	96.245	0.163
1992	48.720	15.180	0.697	96.245	0.163
1993	48.720	15.180	0.697	96.245	0.163
1994	48.720	15.180	0.697	96.245	0.163
1995	48.720	15.180	0.697	96.245	0.163
1996	48.720	15.180	0.697	96.245	0.163
1997	48.720	15.180	0.697	96.245	0.163
1998	48.720	15.180	0.697	96.245	0.163
1999	48.720	15.180	0.697	96.245	0.163
2000	48.720	15.180	0.697	96.245	0.163
2001	48.720	15.180	0.697	96.245	0.163
2002	48.720	15.180	0.697	96.245	0.163
2003	48.720	15.180	0.697	96.245	0.163
2004	48.720	15.180	0.697	96.245	0.163
2005	48.720	15.190	0.697	96.245	0.163
2006	48.720	15.220	0.697	96.245	0.163

Parameter*	NCV	Carbon content	Density	CH_4	CO_2
Year	**GJ/t**	**tC/TJ**	**kg/m3**	**% vol.**	**% vol.**
2007	48.720	15.160	0.697	96.245	0.163
2008	48.720	15.170	0.697	96.245	0.163
2009	48.720	15.200	0.697	96.245	0.163
2010	48.720	15.170	0.697	96.245	0.163
2011	48.720	15.129	0.697	96.245	0.163
2012	48.721	15.140	0.700	95.903	0.194
2013	48.697	15.168	0.701	95.759	0.247
2014	48.612	15.121	0.698	96.035	0.219
2015	48.771	15.214	0.714	94.298	0.411
2016	48.752	15.260	0.708	94.898	0.265
2017	47.152	15.314	0.737	91.877	1.093
2018	48.500	15.225	0.712	94.411	0.355
2019	47.899	15.273	0.719	93.700	0.480
2020	47.960	15.210	0.719	93.738	0.739
2021	47.960	15.210	0.719	93.738	0.739

** Determined for standard conditions (20°C, 101.3 kPa)*

There is no information on passport certificates of physical and chemical parameters of gas for 2021, so the last year's parameters of consumed gas were taken as the closest by expert opinion.

The national value of carbon content in natural gas is different from the default value [1] by 0.5-1.2%. The average deviation from the value is approximately minus 0.5 %, which is in the range of deviation from the default values [1].

Since fluctuation of carbon content in natural gas over the period of 2004-2012 was extremely low and ranged from minus 0.3% to plus 0.3%, and taking into account that the natural gas supply into Ukraine sources remained unchanged over the past decades, the carbon content of natural gas in the period of 1990-2003 was adopted as the average of its value for the period of 2004-2010, and amounted to 15.18 t/TJ.

Information about the natural gas NCV, density, and component composition is not available for 1990-2010 period, so the corresponding values were taken based on data in 2011.

A2.6.2 Hard coal

In 2017, research work "Calculations of Greenhouse Gas Emissions from Coal Combustion in Thermal Power Plants of Ukraine for 1990 – 2015" was carried out by Coal Energy Technology Institute of NASU in the framework of realization of Agreement between Ministry of Energy and Coal Industry of Ukraine and Ministry of Foreign Affairs of Denmark on development and cooperation for the Ukraine-Denmark Energy Center [11] and implemented in current submission. Similar calculations for 2016 – 2020 were carried out on the basis of this research work.

Due to the results of the research work, methodology to estimate NCV, carbon content and oxidation factor for coals combusted at all 15 acting TPPs in Ukraine was upgraded. Proposed methodology also accounts for the fraction of volatile components in the coal itself when determining the carbon content.

When developing the methodology two specific thermal groups of coals were taken into account: bituminous and low-reactive coal. Thermal coal division on 2 groups with the definition of average value Cdaf (the part of carbon in coal on "dry ash-free" basis) for each of them is based on the following considerations. Among the 15 large TPPs of Ukraine 7 are designed to burn bituminous coal (Zuyivska, Vuglegirska, Zaporizka, Kurakhisvska, Ladyzhynska, Dobrotvirska, Burshtynska), 7 – for burning of low-reactive coal (Tripilska, Zmiyivska, Prydniprovska, Starobeshivska, Slovyanska, Luganska, Kryvorizka – anthracite of grade A and semi-anthracite of grade P; during recent years these TPPs have been redesigning to burn bituminous coal and this is reflected in calculations) [12].

Carbon content on dry ash free basis Cdaf is divided to the same groups – bituminous (Cdaf = 76-85%) and low-reactive coal (Cdaf = 89.5-93.3%). Afterwards, it was formed the list of documents that gave the most reliable input data for calculating CO_2 emissions from coal combustion at thermal power plants. This list is presented in Table A2.10.

According to the National standards DSTU ISO 17246:2010 "Coal. Proximate analysis", DSTU ISO 17247:2010 "Coal. Ultimate analysis", GOST 27313-95 (ISO 1170-77) "Mineral solid fuel. Designation of quality characteristics and the formula calculation results analysis for different bases of fuel", Cdaf values are calculated on the basis of the analytical values of carbon, ash and water content obtained on samples enriched to ash content less than 10%. Cdaf values are given in Ukrainian "Certificates of genetic, technological and qualitative characteristics" and include both non-volatile carbon and carbon, which is part of the volatile substances.

Table A2.10. Data sources for the estimates on physical and chemical properties for coals combusted at TPPs

№	Type of source	Name	Input data
1	The annual report for each TPP	Form 3-tech-TPP "Technical & economic performance of the equipment"	Annual consumption of fuel B, tCE The share of coal in the fuel bcoal, % NCV Qir, kcal/kg Moisture content Wtr, % Ash content Ar, % Heat loss with unburned carbon q4, % (Average per year)
2	Certificate	Certificates of genetic, technological and qualitative characteristics of coal products	Organic carbon on dry ash-free coal base Cdaf, %
3	Statistical digest	Digests of quality, volume of coal mining and of coal processing products (annual)	Weight fraction of producers and coal grades in groups of manufactured coal: grades A, P – group of low-reactive coal (Vdaf < 18%) grades D, DG, G – group of bituminous coal (Vdaf = 35-45%)

According to the developed methodology [11] the mass of coal combusted is estimated as following:

$$B_{coal} = (B \cdot \frac{b_{coal}}{100}) \cdot (\frac{7000}{Q_i^r}), \text{ tons} \quad \text{(A5)}$$

Where:
B – annual consumption of fuel, tCE (by reports of 3-tech-TPP);
b_{coal} – the part of coal in total fuel, % (by reports of 3-tech-TPP);
Q^r_i – net calorific value of coal, kcal/kg (by reports of 3-tech-TPP).
NCV values for coals in MJ/kg can be estimated according to the formula:

$$NCV_{coal} = Q_i^r \cdot 4.187/1000, \text{ MJ/kg} \quad \text{(A6)}$$

Where: NCV_{coal} – NCV of coals combusted, MJ/kg.
Carbon content in the coals was estimated according to the formula:

$$K_c = 10 \cdot C^r / NCV_{coal}, \text{ t/TJ} \quad \text{(A7)}$$

Where: Kc – carbon content in coal, t/TJ;
C^r – the part of carbon in coal on "as received" basis estimated as followed:

$$C^r = C^{daf} \cdot (1 - \frac{W_t^r}{100} - \frac{A^r}{100}), \% \quad \text{(A8)}$$

Where: C^{daf} – the part of carbon in coal on "dry-ash-free" basis, %;
W^r_t , A^r – moisture content and ash content on "as received" basis by reports of 3-tech-TPP;

Carbon oxidation factor was estimated as followed:

$$K_o = 1 - B_c / (B_{coal} \cdot \frac{C^r}{100}), \text{ share} \quad \text{(A9)}$$

Where: K_o – carbon oxidation factor for coals combusted, share;
B_c – the mass of unburned carbon, t, and estimated as:

$$B_c = (B \cdot q_4/100) \cdot (\frac{7000}{7800}), \text{ t} \quad \text{(A10)}$$

Where: 7800 kcal/kg (32.66 MJ/kg) – NCV of unburned carbon in flue ash and in slag, in accordance to industry standard GKD 34.09.103-96 "Calculation of reporting technical and economic indicators of thermal power plant equipment efficiency Guidance"; 7000 kcal/kg (29.31 MJ/kg) – NCV of CE; *q4* – heat loss with unburned carbon, % (by reports of 3-tech-TPP).

To determine the weighted average carbon content Cdaf for grades and groups of grades of Ukrainian thermal coal for the years 2003-2021 were used:

- the annual "Digests of quality, volume of coal mining and of coal processing products", published by the Institute «UkrNDIvuglezbagachennya»;
- the "Certificates of genetic, technological and qualitative characteristics" of coal products that they developed for a 4-year period for each manufacturer and type of coal by the institute "UkrNDIvuglezbagachennya";
- the Institute "UkrNDIvuglezbagachennya" intermediate report on the work "The generalization of carbon content dependence of coal quality per grades in different periods, which differ by varying share of contribution of domestic deposits of Donbas and Lviv-Volyn basin".

The data on TPP units are presented in the tables A.2.11 – A.2.14.

Table A2.11. Coal consumption at TPPs in Ukraine, kt

TPP	Grade	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Zmiyivska	A,P/ G,DG	4204	3111	1870	2140	2701	552	1086	647	1066	1395	1421	1080
Tripilska	A,P/G, DG	1911	1960	1407	1285	2076	1311	1434	464	1112	1416	1089	997
Vuglegirska	G, DG	1491	1963	1450	1725	2051	2002	2241	1936	2012	1963	1564	1559
Starobeshivska	A, P	3438	4033	2658	2232	2489	2107	2211	2211	3274	3322	3322	3332
Slovyanska	A, P	689	1159	1038	1303	1361	1075	1407	1049	1629	1629	1480	911
Luganska	A, P	2461	1238	2060	1937	2841	1267	1606	1259	1063	634	545	937
Zuyivska	G, DG	1024	2668	2497	2441	2796	1560	1776	1776	1680	1191	1191	1191
Kurakhisvska	G, DG	4633	4855	2814	2662	3386	3368	3504	3921	3669	3406	3083	3119
Zaporizka	G, DG	3967	2891	2263	2074	2278	2656	2366	2846	2864	2483	2354	2159
Prydniprovska	A,P/ G, DG	2061	3104	1486	1756	1761	794	1354	689	908	922	742	612
Kryvorizka	A,P/ G, DG	6539	4015	1510	1848	2789	1241	2310	1222	1126	711	982	1003
Ladyzhynska	G, DG	2854	3088	1818	1676	1848	2746	2072	2601	2002	1930	1478	1462
Burshtynska	G, DG	4523	4024	1892	3201	3040	4845	4289	4483	5057	4499	3266	4112
Dobrotvirska	G, DG	376	1037	1248	944	754	1158	1164	1349	1240	1098	972	945
Myronivska	G, DG	317	174	135	41	349	80	260	240	266	165	144	144
Myronivska	A, P	195	3	-	39	2701	125						
Totally in Ukraine		40684	39322	26146	27304	32524	26888	29079	26692	28966	26807	23643	23563

Table A2.12. NCV of coal supplied to TPPs in Ukraine, MJ/kg (as received)

TPP	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Zmiyivska	20.75	19.28	19.23	22.00	21.91	23.54	23.23	22.48	21.85	22.79	22.20	21.99
Tripilska	19.28	19.05	18.37	22.27	21.89	23.36	21.93	21.73	22.29	22.26	21.16	21.38
Vuglegirska	18.07	17.77	19.40	20.70	21.45	22.39	22.35	21.86	22.20	21.76	21.52	22.04
Starobeshivska	20.22	20.86	18.31	19.82	21.95	23.15	23.30	23.30	23.30	23.30	23.30	23.30
Slovyanska	21.73	20.75	17.67	20.73	22.70	23.60	23.30	24.32	23.01	22.36	21.44	20.14

TPP	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Luganska	18.16	19.24	18.41	24.23	23.90	23.17	23.51	23.84	23.52	22.81	23.05	22.82
Zuyivska	16.22	16.08	16.43	20.06	19.75	20.73	19.85	19.85	19.85	19.85	19.85	19.85
Kurakhisvska	14.89	15.47	15.39	18.55	17.88	17.94	17.38	18.07	18.67	18.50	18.71	17.80
Zaporizka	17.03	15.77	16.45	19.85	21.85	21.11	21.02	20.90	21.01	21.46	20.97	20.91
Prydniprovska	21.13	19.56	18.37	20.96	23.72	22.32	23.47	23.29	21.83	21.80	21.30	21.00
Kryvorizka	21.51	18.59	18.41	21.53	24.74	23.35	24.03	23.42	23.82	23.65	22.65	22.47
Ladyzhynska	14.74	13.98	12.90	19.78	20.76	20.40	20.91	20.83	20.93	21.06	20.84	20.51
Burshtynska	16.70	16.90	16.63	19.14	20.53	20.76	20.74	21.06	21.52	21.27	20.93	21.49
Dobrotvirska	18.74	17.69	15.47	21.42	21.31	20.81	21.01	21.15	21.99	21.56	21.09	21.91
Myronivska	13.69	13.47	16.48	17.48	17.95	19.00	19.98	19.69	18.61	18.83	18.82	18.82
Myronivska	21.14	18.23	0.00	23.02	20.51	22.64						
Totally in Ukraine	18.45	17.68	17.13	20.58	21.58	21.29	21.46	21.21	21.51	21.46	21.20	21.15

Table A2.13. Carbon content factor Kc of coal supplied to TPPs in Ukraine, t/TJ

TPP	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Zmiyivska	28.81	29.33	28.72	28.24	28.86	27.46	28.00	28.24	25.38	26.26	26.10	25.75
Tripilska	28.64	29.03	28.85	28.64	28.89	27.83	28.49	28.54	26.02	25.67	25.73	25.14
Vuglegirska	26.14	26.22	25.43	25.16	25.38	25.10	25.14	25.25	25.20	25.16	25.51	25.09
Starobeshivska	27.90	28.12	28.13	28.61	28.76	27.59	27.66	27.66	27.66	27.66	27.66	27.66
Slovyanska	28.23	28.90	28.82	28.41	28.51	27.68	27.66	27.45	27.52	27.03	26.33	26.40
Luganska	29.37	28.06	28.91	27.19	28.13	28.48	28.21	28.09	28.13	28.24	28.27	28.22
Zuyivska	27.02	27.06	26.63	25.56	25.89	25.38	25.73	25.73	25.73	25.73	25.73	25.73
Kurakhisvska	26.39	26.77	25.99	25.90	26.27	26.06	26.27	25.79	25.43	25.46	25.47	25.95
Zaporizka	26.75	26.59	25.83	25.33	25.17	25.32	25.30	25.28	25.27	25.18	25.30	25.35
Prydniprovska	28.82	29.52	28.92	28.67	28.21	28.38	27.81	27.97	25.34	25.28	25.33	25.51
Kryvorizka	27.79	28.25	28.33	27.64	27.21	27.59	27.10	27.52	27.07	26.66	25.43	26.05
Ladyzhynska	27.74	26.52	26.14	25.83	25.68	26.16	25.49	25.40	25.53	25.41	25.39	25.31
Burshtynska	27.41	26.65	25.99	25.65	25.54	25.75	25.92	25.65	25.34	25.26	25.45	25.37
Dobrotvirska	25.99	26.45	25.91	24.42	24.84	25.51	27.05	25.41	25.16	25.35	25.39	25.46
Myronivska	27.64	27.96	26.46	25.75	25.92	25.73	26.84	25.59	25.47	25.60	25.50	25.50
Myronivska	28.80	30.45	-	27.65	27.90	28.04	28.00					
Totally in Ukraine	27.77	27.74	27.31	26.78	27.05	26.42	26.64	26.24	25.99	25.93	25.97	25.99

Table A2.14. Carbon oxidation factor Ko of coal at TPPs in Ukraine

TPP	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021
Zmiyivska	0.914	0.886	0.906	0.913	0.944	0.945	0.927	0.969	0.993	0.985	0.981	0.982
Tripilska	0.896	0.880	0.837	0.875	0.921	0.934	0.930	0.930	0.967	0.978	0.961	0.971
Vuglegirska	0.994	0.993	0.996	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Starobeshivska	0.898	0.899	0.906	0.850	0.922	0.956	0.958	0.958	0.958	0.958	0.984	0.984
Slovyanska	0.964	0.898	0.889	0.915	0.952	0.968	0.970	0.967	0.960	0.950	0.940	0.944
Luganska	0.851	0.784	0.774	0.944	0.948	0.936	0.936	0.939	0.945	0.917	0.920	0.929
Zuyivska	0.992	0.993	0.991	0.995	0.995	0.997	0.997	0.997	0.997	0.997	0.997	0.997
Kurakhisvska	0.955	0.968	0.959	0.976	0.977	0.976	0.974	0.976	0.978	0.970	0.965	0.965
Zaporizka	0.994	0.992	0.992	0.994	0.996	0.995	0.995	0.996	0.996	0.997	0.996	0.991
Prydniprovska	0.900	0.908	0.873	0.902	0.930	0.901	0.915	0.922	0.983	0.991	0.989	0.994
Kryvorizka	0.966	0.947	0.955	0.958	0.949	0.918	0.933	0.926	0.926	0.935	0.969	0.950
Ladyzhynska	0.988	0.987	0.983	0.995	0.996	0.995	0.996	0.995	0.996	0.995	0.994	0.993
Burshtynska	0.988	0.988	0.980	0.979	0.983	0.986	0.984	0.988	0.987	0.987	0.990	0.988

<table>
<tr><th>TPP</th><th>1990</th><th>1995</th><th>2000</th><th>2005</th><th>2010</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th></tr>
<tr><td>Dobrotvirska</td><td>0.980</td><td>0.974</td><td>0.964</td><td>0.980</td><td>0.982</td><td>0.983</td><td>0.983</td><td>0.981</td><td>0.984</td><td>0.984</td><td>0.985</td><td>0.978</td></tr>
<tr><td>Myronivska</td><td>0.935</td><td>0.887</td><td>0.973</td><td>0.990</td><td>0.990</td><td>0.990</td><td>0.968</td><td rowspan="2">0.988</td><td rowspan="2">0.994</td><td rowspan="2">0.995</td><td rowspan="2">0.995</td><td rowspan="2">0.995</td></tr>
<tr><td>Myronivska</td><td>0.562</td><td>0.606</td><td>-</td><td>0.937</td><td>0.973</td><td>0.961</td><td>0.927</td></tr>
<tr><td>Totally in Ukraine</td><td>0.943</td><td>0.937</td><td>0.926</td><td>0.948</td><td>0.961</td><td>0.971</td><td>0.968</td><td>0.976</td><td>0.979</td><td>0.978</td><td>0.980</td><td>0.980</td></tr>
</table>

In 1990-1991 the share of coal in coal-firing power units did not exceed 52% in terms of coal equivalent (CE), but in the years 1993-2001 it ranged from 65 to 80%. In 2002, due to the above mentioned coal quality improvement, it became possible to reduce oil and gas addition when coal firing, so the share of coal in coal-firing power units started to grow, and since 2009 it has stabilized at 97-98%.

In 1990-1994 the consumption of low-reactive coal at thermal power plants significantly exceed the consumption of bituminous coal, then within 20 years their consumption in CE units was almost the same, but since 2014 the share of anthracite significantly reduced.

A2.6.3 Motor fuels

In 2017, research work "Capacity building of the national GHG inventory system in terms of the development of methodological recommendations for determining national GHG emission factors from the use of motor fuels in the transport sector" was carried out by Ricardo Energy & Environment (United Kingdom), State Enterprise State Road Transport Research Institute (Ukraine) and MASMA (Ukraine) under the Clima East Policy Project [15] and implemented in current submission.

According to the results of the research work, carbon content and NCV for gasoline, diesel oil and LPG (see Table A2.4) consumed in Ukraine were determined for 2014, as well as retrospective values obtained for the whole period up to 1990.

According to the recommendations of research work authors the data in 2015 - 2021 were taken based on 2014.

Applied method is based on the theoretical approach and has been focused on an assessment of the chemical structure of each component in the fuel, namely the mix of different hydrocarbons and their properties, and the proportions of each component in the final fuel formulation. The method takes into account the carbon, hydrogen, oxygen and sulphur content of each individual hydrocarbon, its mass density and its thermodynamic properties.

The general principle of the approach was to consider the number of component fuels from different parts of the refinery process that makes up the blend of fuel and the chemical composition of each of the component parts. The considerations were based on fuel production industry data, fuel standards and expert knowledge of the refinery processing of fuel formulations that have made up the types of gasoline, diesel oil and LPG available on the market in Ukraine since 1990.

At the first stage of the study representative types of market fuels available since 2014 were identified for gasoline, diesel oil and LPG and a market share for each representative fuel type was obtained. At the second stage, blend of components for different fuel types, the chemical composition of components and respectively for the fuel types in whole were evaluated so the carbon content for different fuel types was identified. At the third stage, NCVs for different fuel types were estimated according to Mendeleev formula [15]:

$$NCV\ (MJ/kg) = 0.339*C+1.256*H-0.109*(O-S)-0.025*(W-9H) \qquad (A11)$$

Where: C, H, O, S and W are the mass fractions of carbon, hydrogen, oxygen, sulphur and water in the fuel.

For gasoline the components of 15 different representative types of market fuels available since 1990 were considered as well as the market share of each type in Ukraine in each year from 1990-2014. These are referred to as "Average Fuel Brand Representative (AFBR)".

For diesel oil the components of 12 different representative types of market fuels available since 1990 were considered as well as the market share of each type in Ukraine in each year from 1990-2014. Again, these are referred to as AFBR.

A similar model for LPG as for gasoline and diesel oil was developed, but based on one single AFBR fuel type with a defined mix of these simple components that was considered valid over the whole period from 1990-2014. The AFBR is characterized by a 47% propane component, 47% butane component, 4.9% 'other hydrocarbons' and the remaining mass being non-hydrocarbon residue (including water).

A2.7 Methods to estimate GHG emissions from aircraft equipped with jet engines

To assess GHG emissions from civil aviation aircraft equipped with jet engines, the method was used that corresponds to Tier 3 in accordance with [1]. As activity data, data on aircraft (AC) departures from airports situated in the territory of Ukraine were used. Data on departures (hereinafter - the departure database (DDB)) were provided by the State Enterprise for Air Traffic Service of Ukraine (SE "Ukraeroruh"), and they include the following information for each departure:

- date and time of departure;
- airport of departure and destination;
- airline;
- ICAO code of the AC.

GHG emissions from AC was performed in two stages: preliminary data processing and calculation of GHG emissions.

A2.7.1 Data preprocessing

Data preprocessing includes removing entries from the DDB on departures meeting the following criteria:

- the AC is a helicopter;
- the AC is a military one;
- the AC's engine is a piston one;
- the airport of departure and destination is the same;
- the AC's code is not defined.

A2.7.2 Distribution of GHG emissions between domestic and international aviation

The approach applied to distribution of GHG emissions between domestic and international aviation is consistent with the approach described in [1]. Emissions from domestic aviation include emissions from AC operations where the departure and destination airports are located in the territory of Ukraine. Emissions from international aviation include emissions from AC operations where the departure airport is located in the territory of Ukraine, while the destination airport is outside of Ukraine, or vice versa.

A2.7.3 Estimation of GHG emissions

The GHG estimation was performed in accordance with the detailed methodology EMEP/CORINAIR, 2013 [23], which corresponds to Tier 3 of [1].

Fuel consumption for the "take-off and landing" cycle was taken according to the EMEP/CORINAIR methodology [2], as well as fuel consumption during cruise flight was calculated on the basis of this methodology.

To convert jet fuel consumption from mass units, as shown in [2], into energy ones, the net calorific value for jet kerosene was used, which is 44.1 MJ/kg in accordance with [1].

When calculating emissions of CO_2, the carbon emission factor for jet kerosene was assumed to be 19.5 t of C/TJ according to [1].

Emissions of CO, NOx, NMVOC, N_2O, SO_2, and CH_4 were adopted based on [2] with the data on the type of aircraft and the flight length.

The algorithm for matching the AC type that actually performed the flight and the representative AC, the data on distance and fuel consumption for 2021 year are presented in tables A2.15, A.16 and A.17.

Table A2.15. The correspondence between the representative AC type and the AC type that actually performed the flight

Name of the representative AC	ICAO code of the AC	Name of the representative AC	ICAO code of the AC	Name of the representative AC	ICAO code of the AC
A310	A306	Beech	AC95	DC9	YK42
A310	A30B	Beech	AN28	DHC8	A140
A310	A310	Beech	B350	DHC8	A748
A320	A318	Beech	BE10	DHC8	AN24
A320	A319	Beech	BE20	DHC8	AN26
A320	A320	Beech	BE30	DHC8	AN30
A320	A321	Beech	BE9L	DHC8	AN32
A330	A332	Beech	BE9T	DHC8	AT43
A330	A333	Beech	C425	DHC8	AT45
A340	A342	Beech	C441	DHC8	AT72
A340	A343	Beech	D228	DHC8	AT75
A340	A345	Beech	DHC6	DHC8	ATLA
A340	A346	Beech	F406	DHC8	ATP
A340	C17	Beech	L410	DHC8	B190
ATR72	AN12	Beech	MU2	DHC8	BE12
ATR72	AN22	Beech	P180	DHC8	C160
ATR72	AN70	Beech	PAY1	DHC8	C212
ATR72	C130	Beech	PAY2	DHC8	C27J
ATR72	C30J	Beech	PAY3	DHC8	C295
ATR72	IL18	Beech	PAY4	DHC8	CL2T
ATR72	IL38	Beech	STAR	DHC8	CN35
ATR72	P3	Beech	SW3	DHC8	D328
B727	B703	Beech	SW4	DHC8	DH8A
B727	B712	Beech	SW4	DHC8	DH8B
B727	B721	Cassna	ASTR	DHC8	DH8C
B727	B722	Cassna	BE40	DHC8	DH8D
B737-100	B732	Cassna	C25A	DHC8	E120
B737-100	B733	Cassna	C25B	DHC8	E121
B737-400	B734	Cassna	C25C	DHC8	F27
B737-400	B735	Cassna	C500	DHC8	F50
B737-400	B736	Cassna	C501	DHC8	G159
B737-400	B737	Cassna	C510	DHC8	JS31
B737-400	B738	Cassna	C525	DHC8	JS32
B737-400	B739	Cassna	C550	DHC8	SB20
B747-100-300	B742	Cassna	C551	DHC8	SF34
B747-100-300	B743	Cassna	C560	DHC8	SH36
B747-100-300	C5	Cassna	C56X	F100	A148
B747-100-300	IL76	Cassna	C650	F100	A158
B747-100-300	IL86	Cassna	E50P	F100	C680
B747-100-300	IL96	Cassna	E55P	F100	C750
B747-400*1.5	A225	Cassna	EA50	F100	CL30
B747-400	A124	Cassna	F2TH	F100	CL60
B747-400	B744	Cassna	F900	F100	E135
B747-400	B748	Cassna	FA10	F100	E145
B757	B752	Cassna	FA50	F100	E170
B757	B753	Cassna	FA7X	F100	E190
B757	SU95	Cassna	G150	F100	F100
B757	T204	Cassna	H25A	F100	F70
B767-300	B762	Cassna	H25B	F100	F70
B767-300	B763	Cassna	H25C	F100	FA20
B777	B772	Cassna	HA4T	F100	G250
B777	B788	Cassna	LJ24	F100	G280
BAC111	BA11	Cassna	LJ31	F100	GALX
BAC111	GLF2	Cassna	LJ35	F100	GL5T

Name of the representative AC	ICAO code of the AC	Name of the representative AC	ICAO code of the AC	Name of the representative AC	ICAO code of the AC
BAC111	GLF3	Cassna	LJ40	F100	GLEX
BAC111	GLF6	Cassna	LJ45	F100	GLF5
BAC111	YK40	Cassna	LJ55	F100	J328
BAe146	B461	Cassna	LJ60	F28	A743
BAe146	B462	Cassna	MU30	F28	AN72
BAe146	B463	Cassna	PRM1	F28	GLF4
BAe146*0.5	L29B	Cassna	SBR1	MD81	MD81
Beech*0.5	A270	CRJ145	CRJ1	MD81	MD82
Beech*0.5	B36T	CRJ145	CRJ2	MD81	MD83
Beech*0.5	AN3	CRJ145	CRJ7	MD81	MD87
Beech*0.5	C10T	CRJ145	CRJ9	MD81	MD88
Beech*0.5	C208	DC10	MD11	MD81	MD90
Beech*0.5	E500	DC8	C135	RJ85	RJ1H
Beech*0.5	P46T	DC8	IL62	RJ85	RJ70
Beech*0.5	TBM7	DC8	K35R	RJ85	RJ85
Beech*0.5	TBM8	DC9	DC91	T134	T134
Beech*0.5	PC12	DC9	DC93	T154	T154
Beech	AC90	DC9	DC95		

1 - The conversion factor of double-engine aircrafts into single-engine ones is 0.5.

Table A2.16. Flight statistics for domestic aviation in 2021

Aircraft IcaoId (Representative)	Quantity of flights	Fuel consumed, kg	Distance, km
ATR72	75	60070.47	14598.85
B737-100	18	38297.30	6529.89
B737-400	1198	3393953.31	602669.10
B747-100-300	13	101914.06	4532.38
MD81	8	25828.10	3819.01
BAC111	122	256048.07	58448.88
Beech	150	51021.22	65091.85
Beech*0,5	28	10446.63	12745.41
Cassna	1632	1279124.55	766012.71
CRJ145	8	9332.28	3804.83
DHC8	8934	15869393.44	4202246.53
F100	3710	5922139.26	1696598.51
F28	75	99028.73	24197.79
A320	232	644845.20	103173.80

Table A2.17. Flight statistics for international aviation in 2021

Aircraft IcaoId (Representative)	Quantity of flights	Fuel consumed, kg	Distance, km
A320	1837	11283731.	3274850
A340	25	394849.76	44491.96
ATR72	178	1431600.00	357382.50
B737-100	347	1537667.18	394399.20
B737-400	28477	186715610.40	53141455.15
B747-100-300	33	1335550.55	98627.01
B747-400	165	4789704.89	379439.03
B747-400*1.5	9	595303.30	52458.17
B757	907	11289501.23	2109662.57
B767-300	1512	32585590.78	5362437.78

B777	145	3720944.60	436452.86
BAC111	76	416538.66	156471.94
BAe146	36	181893.52	48558.22
Beech	96	71802.03	118445.83
Beech*0,5	78	74447.34	116611.45
Cassna	2998	27962807.12	4588318.69
CRJ145	329	1007563.04	532485.08
DHC8	643	3559163.77	1153448.26
F100	6843	23520043.78	9467138.19
F28	166	884397.22	339879.31
MD81	79	732663.17	177402.28
A310	72	637331.26	92635.77
A320	11449	71098998.80	18575672.70
A330	393	10874581.32	1575585.54

At the time of the estimation, data on AC flights for 1990-2006 had not been preserved. So the replacement method was used to restore the entire time series, where the passenger flow data was used as the substitute parameter for estimation of fuel consumed. Thus fuel distribution was performed on the basis of data on the number of passengers transported by domestic and international aircrafts. The baseline year for the replacement method was the earliest year for which the DDB is preserved - 2007 based on which specific GHG emission indicators were applied for 1990-2006.

It should be noted that fuel consumption in 1990 was adopted on the basis of the FEB [3]. When estimating fuel consumption for 1991-2006 the fact was taken into account that the structure of the fleet of 1990-2006 gradually changed. As a result the specific consumption of fuels by ACs decreased.

A2.8 The methodology to estimate leakage at transportation and distribution of natural gas

To calculate leaks during transportation and distribution of natural gas the national method was developed based on proposals of the National Academy of Sciences of Ukraine and the Bureau of Complex Analysis and Forecasts «BIAF».

In accordance with the method, carbon dioxide emissions from transportation of natural gas through main pipelines were determined by the formula:

$$Q_{T_{CO2}} = C_{CO_2} \cdot \rho_{CO_2} \cdot K_T \cdot P_T \cdot 10^3, \qquad \text{(A12)}$$

where: $Q_{T_{CO_2}}$ - carbon dioxide emissions during transportation of natural gas, kt;
C_{CO_2} - carbon content in natural gas, %;
ρ_{CO_2} - density of carbon dioxide under normal conditions (2.143 kg/m^3);
K_T - natural gas leak rate in transit, billion m^3/Mt;
P_T - volume of natural gas transportation, Mt.

Methane emissions from transportation through main pipelines were determined in a similar manner:

$$Q_{T_{CH4}} = C_{CH_4} \cdot \rho_{CH_4} \cdot K_T \cdot P_T \cdot 10^3, \qquad \text{(A13)}$$

where: C_{CH_4} - methane content in natural gas, %;
ρ_{CH_4}- density of methane under normal conditions (0.714 kg/m^3);

The input activity data, to which the emission factors $C_{CH_4}, \rho_{CH_4,}$ C_{CO_2}, ρ_{CO_2}, K_D were applied (the values are shown in Table A2.22) were natural gas transportation volumes through main pipelines. These data are available from SSSU and NJSC “Naftogas”.

The leakage volume was calculated on the basis of statistical reporting form 4-MTP, field 2 of section 4 (which corresponds to loss of gas in transit) and field 1, section 3 (which corresponds to production and technology natural gas consumption for non-energy purposes in its transportation) of state statistical reporting form 4-MTP for economic activity 49.5 "Gas transportation through pipelines".

In the national statistics for the period of 1991-1996 there was no data on natural gas losses and its production and technical use as a result of its transportation. In the period up to 2002 only the data on losses were indicated as well as in the energy balance of Ukraine for 1990. Therefore, for the period of 1990-2002 by using complete data for the estimations for 2003-2015 and the available data for 1990-2002 based on expert assessments [25] estimations of leaks in this type of activity throughout the estimation series were conducted by means of extrapolation.

For the calculation of greenhouse gas emissions in transportation of natural gas through main pipelines in accordance with [1] a 2-step approach was used.

Carbon dioxide emissions from gas distribution networks were determined based on the formula:

$$Q_{D_{CO2}} = C_{CO_2} \cdot \rho_{CO_2} \cdot K_D \cdot P_D \cdot 10^3, \quad (A14)$$

where: $Q_{D_{CO2}}$ - carbon dioxide emissions from gas distribution networks, kt;
C_{CO_2} - carbon content in natural gas, %;
ρ_{CO_2} - density of carbon dioxide under normal conditions (2.143 kg/m^3);
K_D - natural gas leak in gas distribution networks factor, billion m^3/mln m^3;
P_D - natural gas consumption, billion m$^{3.}$

Methane emissions from gas distribution systems are determined in a similar way:

$$Q_{D_{CH4}} = C_{CH_4} \cdot \rho_{CH_4} \cdot K_D \cdot P_D \cdot 10^3 \quad (A15)$$

where: C_{CH_4}- methane content in natural gas, %;
ρ_{CH_4}- density of methane under normal conditions (0.714 kg/m^3);

As input activity data, to which the emission factors $C_{CH_4}, \rho_{CH_4}, C_{CO_2}, \rho_{CO_2}, K_D$ were applied (the values are presented in Table A2.22), volumes of natural gas consumption were used, estimated as the sum of field 2, section 4 (which corresponds to natural gas losses in its consumption) and field 1, section 3 (which corresponds to the production and technological consumption of natural gas for non-energy goals at its consumption) of state statistical reporting form 4-MTP for economic activity 35.22 "Gas distribution and supply".

In the national statistics for the period of 1991-1996, there was no data on natural gas losses and its production and technical use from gas distribution systems and in the period up to 2002 only the data on losses were indicated, as well as in the energy balance of Ukraine for 1990. Therefore, for the period of 1990-2002, by using complete data for the estimations for 2003-2015 and the available data for 1990-2002, based on expert assessments, estimations of leaks in this type of activity throughout the estimation series were conducted by means of extrapolation.

To calculate greenhouse gas emissions from gas distribution systems, a 2-step approach was used.

The above method allows for GHG emissions in category 1.B.2.c.1.ii Venting. Gas, which are included in emissions at transportation and distribution of natural gas.

Table A2.18. Parameters of natural gas transportation and distribution in Ukraine, 1990-2021

Year	Transportation, P_T Mt	Consumption, P_D bln m^3	The leak factor in transportation, K_T bln m^3/Mt	The leak factor in distribution, K_D bln m^3/Mt	Greenhouse gas emissions in transportation, Q_T kt CO_2-eq.	Greenhouse gas emissions from gas distribution systems, Q_D kt CO_2-eq.
1990*	182.0	115.42	0.00146	0.00764	4553.54	15155.55
1991*	178.0	111.57	0.00171	0.00851	5239.02	16313.46
1992*	184.0	109.59	0.00187	0.00928	5908.15	17471.37

Year	Transportation, P_T Mt	Consumption, P_D bln m^3	The leak factor in transportation, K_T bln m^3/Mt	The leak factor in distribution, K_D bln m^3/Mt	Greenhouse gas emissions in transportation, Q_T kt CO_2-eq.	Greenhouse gas emissions from gas distribution systems, Q_D kt CO_2-eq.
1993*	177.0	95.53	0.00217	0.01135	6598.22	18629.28
1994*	172.0	83.60	0.00246	0.01377	7280.11	19787.19
1995*	174.0	81.89	0.00265	0.01488	7908.38	20945.10
1996*	174.0	80.49	0.00288	0.01598	8619.39	22103.01
1997*	165.0	76.46	0.00312	0.01770	8847.78	23260.93
1998*	169.0	68.92	0.00336	0.02062	9752.84	24418.84
1999	161.0	69.49	0.00360	0.02239	9949.05	26734.66
2000	150.0	66.70	0.00329	0.01993	8471.30	22837.00
2001	148.2	64.10	0.00297	0.02127	7560.59	23422.56
2002	151.0	65.88	0.00184	0.01777	4769.74	20120.57
2003	158.0	72.80	0.00162	0.01707	4388.99	21358.65
2004	164.0	72.48	0.00154	0.01537	4333.40	19142.69
2005	164.0	73.10	0.00152	0.01427	4274.98	17919.71
2006	156.0	71.00	0.00139	0.01424	3719.68	17378.43
2007	142.5	66.82	0.00244	0.01501	5962.56	17234.71
2008	143.2	63.57	0.00219	0.01337	5394.28	14600.52
2009	114.0	50.21	0.00262	0.01407	5132.40	12141.34
2010	121.0	55.99	0.00218	0.01202	4539.36	11559.86
2011	127.0	56.56	0.00189	0.01252	4114.09	12163.01
2012	108.0	53.42	0.00071	0.01151	1321.41	10527.05
2013	106.0	49.73	0.00101	0.00893	1836.19	7589.29
2014	82.0	41.91	0.00150	0.01042	2116.03	7490.11
2015	79.8	35.45	0.00057	0.01386	769.84	8271.99
2016	90.3	36.33	0.00140	0.01623	2107.95	9884.70
2017	102.9	37.09	0.00039	0.01984	663.91	12424.10
2018	96.2	35.32	0.00040	0.02386	650.12	14209.34
2019	98.5	28.01	0.00040	0.03737	661.21	17520.86
2020	63.0	33.85	0.00041	0.03654	433.37	20713.10
2021	56.2	33.85	0.00041	0.03654	386.74	20713.10

**-expert estimation*

A2.9 Activity data

The array of estimated data on energy use of fuels in CRF category Energy Industries 1.A for 2021 is presented in tables A2.19, A2.20.

Table A2.19. Fuel use by IPCC categories in physical units (stationary combustion) in 2021, t

Name of fuel	1.A.1. a. Main activity Electricity and Heat Production	1.A.1.b. Oil refinery	1.A.1.c. Solid Fuel Production and Other Industries	1.A.2.a. Iron and Steel	1.A.2.b. Non-Ferrous Metals	1.A.2.c. Chemicals	1.A.2.d. Pulp. Paper. and Print	1.A.2.e. Food Processing. Beverages. and Tobacco	1.A.2.f. Non-Metal Minerals	1.A.2.g. Other Industries	1.A.4.a. Commercial/Institutional Sector	1.A.4.b. Residential Sector	1.a.4.c. Agriculture/Forestry/Fishery/Fishing
Hard coal	24995465		165956	2664003	197455	3027	85	46368	1343714	7739	40851	416363	8220
Briquettes, pellets from hard coal	1422		40		10				1228	626	108		
Brown coal	952		429							13	134		3
Briquettes, pellets from brown coal	129										298		2
Non-agglomerated fuel peat	19110		44						67	18859	32		
Briquettes, pellets from peat	43243		452	3		4	44	1205	2706	799	13945	47320	2373
Crude oil, including oil from bituminous materials			1881		100	10			33	16			216
Gas condensate			1490		207					53			20
Natural gas	6527633	31803	504698	1648820	180594	145281	18467	166880	495960	975306	183610	6377628	112119
Charcoal				19	99					76	10.10	132	

Firewood	663841		19444	817	183	2473	648	12320	13866	111149	87520.82	1394654	59444
Fuel briquettes and pellets from wood and other natural materials	273115		2049	8	99	3035	43	6281	11863	12862	12903	796	10220
Biodiesel from oils, sugar and starch crops													
Other types of source fuels	1624302		59112	66646		45		11205	28158	26336	4406	23205	31958
Coke and semi-coke from hard coal, gaseous coke					1096	1799		1275	27528	21305	1	171	
Hard, brown coal, and peat tars				15933	237			2366		2366			
Pitch and pitch coke													
Aviation gaso-line													
Motor gasoline			2878										
Motor fuel composite with bioethanol ... 5% -30%													
Fuel for jet en-gines of the gasoline type													
Oil distillates, other light fractions													
Fuel for jet en-gines of the kerosene type													
Kerosene			186										
Gas oils	3770		26501										
Medium oil distillates, other medium fractions	6838												
Heavy fuel black oils	61550	30596	2624	1647	504	692		523	6852	5207	5523		75
Petroleum oils, heavy oil dis-tillates					234			17	107	680	841	167	617

Propane and butane, liquefied	2953		696	18119	8540	1567	1237	3870	81267	10416	7309.26	393	14225
Ethylene, propylene, petroleum gases, other...			15029		18	6			34	367	3		19
Petroleum coke (including shale)										7			
Other types of oil products	16898	78062		487		48		3	656	2591	428	3	77
Other fuel processing products	818412		789	1253		93		186	78456	25056	905	1779	86
Coke oven gas produced as a byproduct	420013		454713	812675	215	3174		6348	37267	38580	6581		

Table A2.20. Fuel use by IPCC categories in physical units (mobile combustion) in 2021, t

Name of fuel	1.A.3.a. Civil Aviation	1.A.3.b. Road transport	1.A.3.c. Railways	1.A.3.d. Water Transport	1.A.3.e. Other types of transport
Hard coal					
Briquettes, pellets from hard coal					
Brown coal					
Briquettes, pellets from brown coal					
Non-agglomerated fuel peat					
Briquettes, pellets from peat					
Crude oil, including oil from bituminous materi-als					
Gas condensate					
Natural gas					608135
Charcoal					
Firewood					
Fuel briquettes and pellets from wood and other natural materials					
Biodiesel from oils, sugar and starch crops		209			20
Liquid fuels					1684321
Coke and semi-coke from hard coal, gaseous coke					
Hard, brown coal, and peat tars					
Pitch and pitch coke					
Aviation gasoline	32330				
Motor gasoline		1915660			
Motor fuel composite with bioethanol ... 5% - 30%					
Fuel for jet engines of the gasoline type					
Oil distillates, other light fractions					
Fuel for jet engines of the kerosene type	34033.09				
Kerosene					
Gas oils		4042764	118604.50	25923.50	
Medium oil distillates, other medium fractions					
Heavy fuel black oils					

Petroleum oils, heavy oil distillates		1432			
Propane and butane, liquefied		1325299			
Ethylene, propylene, petroleum gases, other...					
Petroleum coke (including shale)					
Other types of oil products					
Other fuel processing products					
Coke oven gas produced as a byproduct					

A2.10 Other matters related to activity data in Energy sector in 2014-2020

As a result of the illegal occupation of the Autonomous Republic of Crimea and the city of Sevastopol by the Russian Federation and its further military invasion in certain areas of Donetsk and Luhansk regions, since 2014 some of the territory of Ukraine temporarily remains out of control of the Government of Ukraine. This fact complicates, and sometimes makes impossible, the process of data collecting so fuel consumption at the above mentioned territories wasn't included in official statistics for 2014 - 2021.

In order to ensure completeness of the GHG emission reporting and to be compliance with the main principles of reporting stated in the Reporting Guidelines according to the decision 24/CP.19, namely the full geographical coverage of the sources and sinks of an Annex I Party, input data for 2014 were adjusted by conducting an analytical study "Development of Proposals and Recommendations on Incorporation of GHG Emission and Absorption in the Special Status Territories (4 Administrative Units) by IPCC Sectors" [14], status of which is “confidential”.

Revaluation of data for 2015-2021 was also performed using the results of the study [14] as well as indicative trends and socio-economic parameters in 2015 – 2021.

Main principles of the data revaluation are presented below.

2014 year. To estimate the activity data that were not included in national and regional energy statistics various scientific approaches were used in work [26].

Certain areas of Donetsk and Luhansk regions. In this case, at the stage 1 regional form 4-MTP was analyzed for 2013 and 2014 and the activity data by different IPCC 2006 categories in energy sector was evaluated. At the stage 2 the indicative difference by different IPCC 2006 categories was evaluated and examined being upper limit of potential underestimation (PUL) of activity data in official data sources. At the stage 3 scientifically based decreasing coefficients (DC) for all potential upper limits by IPCC 2006 categories were evaluated. At the stage 4 revaluation of activity data, including fuel consumption, was performed based on PULs and DCs. Received revaluated data (RD) was added to the activity data at the national level estimated using official statistics by different IPCC 2006 categories. Also, uncertainties for all RDs were evaluated based on expert approaches. Obviously, the uncertainties for all RDs are much higher than for official statistical data that led to certain increase of overall uncertainties.

The Autonomous Republic of Crimea and the city of Sevastopol. At the stage 1 regional form 4-MTP was analyzed for 2013 and the activity data equal to PULs by different IPCC 2006 categories in energy sector was evaluated. At the stage 2 scientifically based DCs for all potential upper limits by IPCC 2006 categories was evaluated based on indicative trends and socio-economic parameters in 2014 according to alternative national and international data sources. Stage 4 is similar to previous appr1oach.

2015-2021 years. Certain areas of Donetsk and Luhansk regions. Taking into account the limitation of reliable information and the fact that civilians' livelihood was closely related with the territory controlled by the Government of Ukraine the common trends of official energy statistics were equal to DCs, wherein the PULs where equal to RDs in 2014.

The Autonomous Republic of Crimea and the city of Sevastopol. The PULs were equal to RDs in 2014. To identify DCs indicative trends and socio-economic parameters in 2015-2021 were used for different IPCC 2006 categories according to alternative national and international data sources.

ANNEX 3

A3.1 Industrial Processes and Product Use (CRF Sector 2)

A3.1.1 Results of GHG inventory in the Industrial Processes and Product Use sector

Table A3.1.1.1 Greenhouse gas emissions in the category Industrial Processes and product use, kt CO_{2-eq}.

Gas	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
1990	111084.50	1206.97	5671.54	0.00	235.82	0.0076	118198.83
1991	95113.32	996.54	5016.39	0.00	188.20	0.0191	101314.47
1992	91918.22	951.49	4320.85	0.00	142.35	0.0305	97332.95
1993	74671.65	729.64	3662.54	0.00	143.57	0.0591	79207.46
1994	63449.66	580.62	2976.58	0.00	161.22	0.0649	67168.15
1995	55124.95	482.50	2370.74	0.00	178.06	0.0677	58156.32
1996	53150.50	466.08	2778.20	0.00	143.24	0.0696	56538.09
1997	58370.98	539.50	3054.92	6.43	146.99	0.128	62118.95
1998	56930.60	549.16	2459.18	13.02	120.64	0.194	60072.80
1999	59534.89	599.42	2633.97	14.14	101.81	0.307	62884.55
2000	63647.91	668.00	3005.28	15.73	115.74	0.421	67453.09
2001	67377.01	1413.53	2928.35	29.05	112.08	0.463	71860.48
2002	68762.58	2150.73	3579.39	64.27	98.66	1.070	74656.70
2003	71437.86	2812.36	3815.51	105.20	77.15	1.991	78250.07
2004	74316.22	3594.17	3264.40	187.26	93.34	3.078	81458.46
2005	73708.19	3047.26	3765.06	285.07	142.33	4.467	80952.38
2006	77985.80	2969.78	3801.67	402.28	111.16	4.274	85274.97
2007	83910.39	2942.32	4946.64	561.13	154.71	5.198	92520.38
2008	82246.93	1634.10	4482.69	647.25	174.24	9.338	89194.54
2009	65058.28	653.63	2203.16	663.76	53.95	9.366	68642.16
2010	69930.11	1069.94	2934.70	743.86	26.67	9.710	74714.99
2011	74138.90	2537.30	3724.32	823.17	0.00	8.416	81232.11
2012	71213.99	2135.33	3491.63	844.29	0.00	10.990	77696.23
2013	68197.67	895.36	2605.90	891.71	0.00	12.543	72603.18
2014	58182.41	633.17	2264.50	869.10	0.00	16.726	61965.90
2015	53339.09	557.31	1697.46	801.65	0.00	19.642	56415.15
2016	54521.52	596.93	2022.39	921.37	0.00	24.372	58086.58
2017	47767.89	1455.38	1578.05	1049.28	0.00	28.557	51879.16
2018	50520.50	3030.72	1497.52	1395.83	0.00	33.445	56478.01
2019	50298.48	3374.45	2202.40	1685.00	0.00	38.789	57599.12
2020	48399.05	3455.74	2352.47	1751.50	0.00	43.350	56002.11
2021	50000.68	3896.96	2511.81	1901.02	0.00	48.942	58359.40

Table A3.1.1.2 Greenhouse gas emissions from Cement Production (CRF category 2.A.1)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Cement production, kt	22729.10	21744.50	20121.10	15011.60	11434.70	7626.80	5020.60	5101.00
Clinker production, kt	17455.70	16559.20	16084.60	11879.00	9267.30	6339.20	4027.40	4510.50
CaO content in clinker, %	65.46	65.46	65.56	65.72	65.84	65.64	65.86	65.66
MgO content in clinker, %	1.88	1.81	1.80	1.63	1.94	1.85	2.28	2.23
CaO content in clinker from non-carbonate source, %	28.10	28.10	23.46	23.17	25.27	22.85	9.52	9.35
MgO content in clinker from non-carbonate source, %	3.33	3.16	2.91	2.90	2.98	2.80	1.21	1.23
Emission factor, tons of CO_2/ton of clinker	0.528	0.528	0.529	0.528	0.528	0.527	0.526	0.525
Correction factor for CKD, p.u.	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Implied emission factor, tons of CO_2/ton of clinker	0.5386	0.5386	0.5396	0.5386	0.5386	0.5375	0.5365	0.5355
CO_2 emissions, kt	9400.94	8918.12	8678.92	6397.55	4990.99	3407.57	2160.78	2415.37
SO_2 emission factor, kg/t	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SO_2 emissions, kt	6.8187	6.5234	6.0363	4.5035	3.4304	2.2880	1.5062	1.5303
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Cement production, kt	5591.20	5828.10	5311.40	5786.30	7156.50	8922.70	10647.84	12164.54
Clinker production, kt	5215.40	4742.79	4239.06	4647.77	5291.62	6784.10	8117.40	9181.00
CaO content in clinker, %	65.55	65.51	65.84	65.44	65.82	65.58	65.61	65.69
MgO content in clinker, %	2.30	2.39	2.24	2.12	1.80	1.62	2.01	1.95
CaO content in clinker from non-carbonate source, %	10.89	9.29	10.80	7.21	6.32	6.23	5.13	5.31
MgO content in clinker from non-carbonate source, %	1.31	1.09	1.40	0.81	0.85	0.75	0.78	0.73
Emission factor, tons of CO_2/ton of clinker	0.524	0.524	0.523	0.522	0.522	0.522	0.515	0.511
Correction factor for CKD, p.u.	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Implied emission factor, tons of CO_2/ton of clinker	0.5345	0.5345	0.5335	0.5324	0.5324	0.5324	0.5253	0.5212
CO_2 emissions, kt	2787.52	2534.92	2261.37	2474.65	2817.47	3612.12	4264.07	4785.32
SO_2 emission factor, kg/t	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SO_2 emissions, kt	1.6774	1.7484	1.5934	1.7359	2.1470	2.67681	3.194352	3.649362

Continuation of Table A3.1.1.2

Year	2006	2007	2008	2009	2010	2011	2012	2013
Cement production, kt	13739.18	15018.83	14918.20	9503.37	9472.12	10579.64	9842.70	9856.50
Clinker production, kt	10522.00	11757.40	11981.30	5038.30	5583.90	7484.60	6279.198	6404.20
CaO content in clinker, %	65.84	65.90	65.95	66.09	65.88	65.81	65.66	65.54
MgO content in clinker, %	1.80	1.76	1.80	1.54	1.49	1.28	1.32	1.14
CaO content in clinker from non-carbonate source, %	6.32	5.03	4.82	4.01	2.23	2.41	2.18	0.70
MgO content in clinker from non-carbonate source, %	0.91	0.68	0.68	0.55	0.30	0.07	0.11	0.08
Emission factor, tons of CO_2/ton of clinker	0.511	0.514	0.515	0.504	0.506	0.511	0.512	0.520
Correction factor for CKD, p.u.	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Implied emission factor, tons of CO_2/ton of clinker	0.5212	0.5243	0.5253	0.5141	0.5161	0.5212	0.5226	0.5304
CO_2 emissions, kt	5484.27	6164.16	6293.77	2590.08	2881.96	3901.12	3281.46	3396.78
SO_2 emission factor, kg/t	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SO_2 emissions, kt	4.121754	4.505649	4.47546	2.851011	2.841636	3.173892	2.95281	2.95695
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Cement production, kt	8854.35	8848.75	9111.70	9492.6	9456.7	9578.8	10134.55	11403.44
Clinker production, kt	6064.639	6062.925	6695.06	6551.55	6845.71	7466.2	7648.45	8175.13
CaO content in clinker, %	65.74	65.51	65.75	65.93	65.95	66.09	66.04	65.94
MgO content in clinker, %	1.59	1.43	1.37	1.35	1.34	1.44	1.35	1.34
CaO content in clinker from non-carbonate source, %	0.0048	0.0	0.0	0.0	0.0	1.83	1.54	1.53
MgO content in clinker from non-carbonate source, %	0.0016	0.0	0.0	0.0	0.0	0.00	0.00	0.27
Emission factor, tons of CO_2/ton of clinker	0.533	0.530	0.531	0.532	0.532	0.52	0.521	0.52
Correction factor for CKD, p.u.	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Implied emission factor, tons of CO_2/ton of clinker	0.5440	0.5406	0.5417	0.543	0.543	0.53	0.531	0.531
CO_2 emissions, kt	3299.19	3277.51	3626.98	3557.11	3716.22	3960.57	4064.9	4338.53
SO_2 emission factor, kg/t	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SO_2 emissions, kt	2.65	2.65	2.73	2.85	2.84	2.87	3.04	3.42

Table A3.1.1.3 Greenhouse gas emissions from Lime Production (CRF category 2.A.2)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Amount of lime produced, kt	8676.60	7648.30	7484.10	5923.80	4662.70	3901.90	3339.40	3534.60	3352.30	3386.70	3631.40	4366.60	4456.10	4895.90	5301.67	5341.74
Amount of quick lime, kt	3902.60	3440.09	3366.23	2664.43	2097.21	1755.01	1502.01	1589.81	1507.81	1523.29	1633.35	1964.03	2004.29	2202.10	2384.61	2719.18
Amount of slaked lime, kt	4774.00	4208.21	4117.87	3259.37	2565.49	2146.89	1837.39	1944.79	1844.49	1863.41	1998.05	2402.57	2451.81	2693.80	2917.06	2622.56
Amount of calcium quick lime, kt	3317.21	2924.08	2861.30	2264.77	1782.63	1491.76	1276.71	1351.34	1281.64	1294.80	1388.35	1669.43	1703.65	1871.79	2026.92	2311.30
Amount of dolomite quick lime, kt	585.39	516.01	504.93	399.66	314.58	263.25	225.30	238.47	226.17	228.49	245.00	294.60	300.64	330.32	357.69	407.88
Amount of slaked lime in dry mass, kt	3437.28	3029.91	2964.87	2346.75	1847.15	1545.76	1322.92	1400.25	1328.03	1341.66	1438.60	1729.85	1765.30	1939.54	2100.28	1888.24
Amount of lime in dry mass, kt	7339.88	6470.00	6331.10	5011.18	3944.36	3300.77	2824.93	2990.06	2835.84	2864.95	3071.95	3693.88	3769.59	4141.64	4484.89	4607.42
Amount of CaO in quick calcium lime, kt	3167.94	2792.49	2732.54	2162.85	1702.41	1424.63	1219.26	1290.53	1223.96	1236.53	1325.87	1594.30	1626.98	1787.55	1935.71	2207.29
Amount of MgO in quick calcium lime, kt	46.44	40.94	40.06	31.71	24.96	20.88	17.87	18.92	17.94	18.13	19.44	23.37	23.85	26.20	28.38	32.36
Amount of CaO in quick dolomite lime, kt	327.82	288.97	282.76	223.81	176.17	147.42	126.17	133.54	126.66	127.96	137.20	164.98	168.36	184.98	200.31	228.41
Amount of MgO in quick dolomite lime, kt	231.23	203.83	199.45	157.87	124.26	103.98	88.99	94.20	89.34	90.25	96.78	116.37	118.75	130.47	141.29	161.11
Amount of CaO and MgO in quick lime, kt	2577.96	2272.43	2223.65	1760.06	1385.36	1159.32	992.19	1050.19	996.02	1006.24	1078.95	1297.39	1323.98	1454.65	1575.21	1416.18
Stoichiometric values for CaO	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Stoichiometric values for MgO	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913
LKD	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
CO_2 emissions from calcium quick lime, kt	2579.81	2274.07	2225.25	1761.32	1386.36	1160.15	992.90	1050.94	996.74	1006.97	1079.73	1298.32	1324.94	1455.70	1576.35	1797.51
CO_2 emissions from dolomite quick lime, kt	477.82	421.19	412.15	326.22	256.77	214.88	183.90	194.65	184.61	186.51	199.98	240.47	245.40	269.62	291.96	332.93
CO_2 emissions from slaked lime, kt	2064.17	1819.54	1780.48	1409.28	1109.26	928.27	794.45	840.88	797.52	805.70	863.91	1038.82	1060.11	1164.74	1261.27	1133.94
Emission factor from quick lime, t/t	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Emission factor from slaked lime, t/t	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Total CO_2 emissions, kt	5121.81	4514.80	4417.87	3496.82	2752.40	2303.29	1971.25	2086.48	1978.87	1999.17	2143.62	2577.61	2630.44	2890.05	3129.58	3264.38
Total emission factor, t/t	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.709

Continuation of Table A3.1.1.3

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Amount of lime produced, kt	5450.25	5687.77	5127.97	4100.74	4241.08	4578.70	4482.50	3968.30	3183.80	3022.35	3324.90	2901.73	3113.19	2922.19	3045.68	3088.61
Amount of quick lime, kt	2671.66	2811.51	2407.59	2403.38	2494.77	4101.10	4047.80	3739.50	2884.89	2758.35	2946.66	2529.15	2765.36	2700.58	2859.59	2898.50
Amount of slaked lime, kt	2778.59	2876.25	2720.38	1697.36	1746.31	477.60	434.70	228.80	298.91	264.00	378.24	372.58	347.82	221.60	186.09	190.11
Amount of calcium quick lime, kt	2270.91	2389.78	2046.45	2042.87	2120.55	3485.94	3440.63	3178.58	2452.15	2344.59	2504.66	2149.77	2350.56	2295.50	2430.65	2463.72
Amount of dolomite quick lime, kt	400.75	421.73	361.14	360.51	374.22	615.17	607.17	560.93	432.73	413.75	442.00	379.37	414.80	405.09	428.94	434.77
Amount of slaked lime in dry mass, kt	2000.58	2070.90	1958.67	1222.10	1257.34	343.87	312.98	164.74	215.22	190.08	272.33	268.26	250.43	159.55	133.99	136.88
Amount of lime in dry mass, kt	4672.24	4882.41	4366.26	3625.48	3752.11	4444.97	4360.78	3904.24	3100.10	2948.43	3218.99	2797.41	3015.80	2860.14	2993.57	3035.38
Amount of CaO in quick calcium lime, kt	2168.72	2282.24	1954.36	1950.94	2025.13	3329.07	3285.80	3035.54	2341.81	2239.09	2391.95	2053.03	2244.79	2192.20	2321.27	2352.86
Amount of MgO in quick calcium lime, kt	31.79	33.46	28.65	28.60	29.69	48.80	48.17	44.50	34.33	32.82	35.07	30.10	32.91	32.14	34.03	34.49
Amount of CaO in quick dolomite lime, kt	224.42	236.17	202.24	201.88	209.56	344.49	340.02	314.12	242.33	231.70	247.52	212.45	232.29	226.85	240.21	243.47
Amount of MgO in quick dolomite lime, kt	158.30	166.58	142.65	142.40	147.82	242.99	239.83	221.57	170.93	163.43	174.59	149.85	163.85	160.01	169.43	171.74
Amount of CaO and MgO in quick lime, kt	1500.44	1553.18	1469.01	916.57	943.01	257.90	234.74	123.55	161.41	142.56	204.25	201.19	187.82	119.67	100.49	102.66
Stoichiometric values for CaO	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Stoichiometric values for MgO	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913	0.913
LKD	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
CO_2 emissions from calcium quick lime, kt	1766.10	1858.55	1591.54	1588.75	1649.17	2711.03	2675.80	2472.00	1907.05	1823.41	1947.89	1671.89	1828.05	1785.22	1890.33	1916.05
CO_2 emissions from dolomite quick lime, kt	327.11	344.23	294.78	294.26	305.45	502.12	495.60	457.85	353.21	337.72	360.78	309.66	338.58	330.65	350.12	354.88
CO_2 emissions from slaked lime, kt	1201.40	1243.63	1176.23	733.90	755.07	206.50	187.95	98.93	129.24	114.15	163.54	161.10	150.39	95.82	80.46	82.20
Emission factor from quick lime, t/t	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Emission factor from slaked lime, t/t	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Total CO_2 emissions, kt	3294.61	3446.41	3062.55	2616.92	2709.68	3419.66	3359.35	3028.77	2389.51	2275.28	2472.21	2142.65	2317.02	2211.69	2320.91	2353.13
Total emission factor, t/t	0.705	0.706	0.701	0.722	0.722	0.769	0.770	0.776	0.771	0.772	0.768	0.766	0.768	0.773	0.775	0.775

Table A3.1.1.4 Greenhouse gas emissions from Glass Production (CRF category 2.A.3)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total glass production, kt	995.01	990.35	913.39	810.72	686.71	653.35	491.10	414.86	397.93	406.34	407.32	1053.87	1085.80	990.52	999.05	993.02
Limestone use, kt	23.29	23.09	19.84	15.50	10.25	8.84	10.89	7.67	6.95	7.31	7.35	76.72	78.07	74.04	74.40	74.15
Dolomite use, kt	198.17	197.29	182.60	163.00	139.33	132.97	98.08	83.53	80.30	81.90	82.09	168.08	174.17	155.98	157.61	156.46
Limestone and dolomite use, kt	221.47	220.38	202.43	178.50	149.58	141.81	108.97	91.19	87.25	89.21	89.44	244.80	252.24	230.03	232.02	230.61
Use of soda in glass production, kt	197.43	197.68	187.09	173.38	146.86	139.73	106.70	90.16	86.79	89.39	88.99	244.49	236.39	215.86	215.38	213.11
CO_2 emissions from use of limestone, kt	10.19	10.11	8.73	6.78	4.50	3.89	4.76	3.34	3.04	3.16	3.20	33.75	34.33	32.58	32.74	32.63
CO_2 emissions from use of dolomite, kt	94.08	94.03	86.50	75.72	65.17	61.86	45.79	39.05	37.62	38.54	38.61	79.06	82.82	74.21	75.27	74.88
CO_2 emissions from use of soda, kt	82.75	82.86	78.42	72.67	61.56	58.57	44.72	37.79	36.38	37.47	37.30	102.48	99.08	90.48	90.28	89.33
CO_2 emission factor for limestone use, t/t	0.43763	0.438	0.440	0.438	0.439	0.440	0.437	0.436	0.437	0.432	0.436	0.440	0.440	0.440	0.440	0.440
CO_2 emission factor for dolomite use, t/t	0.475	0.477	0.474	0.465	0.468	0.465	0.467	0.468	0.469	0.471	0.470	0.470	0.476	0.476	0.478	0.479
CO_2 emission factor for soda use, t/t	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
CO_2 emissions from glass production, kt	187.02	187.00	173.66	155.17	131.22	124.31	95.27	80.19	77.04	79.16	79.12	215.29	216.23	197.27	198.28	196.83
CO_2 emission factor for glass production, t/t	0.188	0.189	0.190	0.191	0.191	0.190	0.194	0.193	0.194	0.195	0.194	0.204	0.199	0.199	0.198	0.198
NMVOC emission factor for glass production, t/t	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
NMVOC emissions from glass production, kt	4.48	4.46	4.11	3.65	3.09	2.94	2.21	1.87	1.79	1.83	1.83	4.74	4.89	4.46	4.50	4.47
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total glass production, kt	1090.96	1218.02	1328.01	988.05	1190.22	1434.95	1377.747	1364.436	1316.39	1181.29	1231.49	1331.84	1315.86	1410.47	1350.74	1496.40
Limestone use, kt	81.55	91.44	100.75	76.17	91.60	112.62	107.42	106.35	103.35	92.54	96.57	104.72	103.45	110.85	106.11	118.05
Dolomite use, kt	171.80	191.40	207.61	153.22	184.73	220.47	212.41	210.39	202.89	182.27	189.91	205.10	202.66	217.26	208.11	230.04
Limestone and dolomite use, kt	253.35	282.85	308.36	229.39	276.33	333.08	319.83	316.74	306.24	274.81	286.49	309.82	306.11	328.12	314.22	348.09
Use of soda in glass production, kt	237.56	265.60	289.94	214.64	256.30	308.38	299.57	299.79	284.87	262.78	271.07	285.19	284.66	300.96	280.54	293.54
CO_2 emissions from use of limestone, kt	35.88	40.25	44.34	33.52	40.32	49.23	46.28	45.50	44.46	40.39	42.14	45.70	45.49	48.84	46.59	51.47
CO_2 emissions from use of dolomite, kt	82.34	91.93	99.46	73.31	88.25	104.05	99.68	99.27	95.17	87.33	91.70	98.85	95.26	103.79	98.88	109.24
CO_2 emissions from use of soda, kt	99.57	111.33	121.53	89.96	107.43	129.26	125.56	125.66	119.40	109.6	113.05	118.94	118.72	125.52	117.00	122.43
CO_2 emission factor for limestone use, t/t	0.440	0.440	0.440	0.440	0.440	0.437	0.431	0.428	0.430	0.436	0.436	0.436	0.440	0.441	0.439	0.436
CO_2 emission factor for dolomite use, t/t	0.479	0.480	0.479	0.478	0.478	0.472	0.469	0.472	0.466	0.479	0.483	0.482	0.470	0.478	0.475	0.475
CO_2 emission factor for soda use, t/t	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
CO_2 emissions from glass production, kt	217.80	243.50	265.33	196.79	236.00	282.54	271.52	270.42	259.04	237.33	246.9	263.49	259.48	278.14	262.47	283.14
CO_2 emission factor for glass production, t/t	0.200	0.200	0.200	0.199	0.198	0.197	0.197	0.198	0.197	0.201	0.200	0.198	0.197	0.197	0.194	0.189
NMVOC emission factor for glass production, t/t	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
NMVOC emissions from glass production, kt	4.91	5.48	5.98	4.45	5.36	6.46	6.20	6.13	5.92	5.32	5.54	5.99	5.92	6.35	6.08	6.73

Table A3.1.1.5 Greenhouse gas emissions from Ammonia Production (CRF category 2.B.1)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Amount of ammonia produced, kt	4863.90	4603.60	4719.30	3916.50	3539.50	3776.30	4017.20	4132.20
Natural gas consumption of, mln m3	6122.5476	5841.0937	6193.6565	5003.9750	4697.8722	4687.2946	5179.1550	5062.3066
Carbon content in natural gas, t/TJ	15.18	15.18	15.18	15.18	15.18	15.18	15.18	15.18
Net calorific value of fuel combustion, TJ/mln m^3	0.03335	0.03338	0.03339	0.03340	0.03340	0.03340	0.03340	0.03340
Stoichiometric ratio between CO_2 and C mol. weight	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667
Urea production, kt	2137.69	2228.52	2368.45	2347.16	2284.82	2419.75	2480.24	2437.9
Stoichiometric ratio of CO_2 to urea	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733
CO_2 emission factor, t/t	2.015	2.002	2.071	1.936	1.994	1.838	1.945	1.845
CO emission factor, t/t	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006
NMVOC emission factor, t/t	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009
NO_x emission factor, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_2 emission factor, t/t	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
CO_2 emissions, kt	9798.963	9218.379	9775.251	7581.556	7059.088	6941.392	7811.609	7625.275
CO emissions, kt	0.0292	0.0276	0.0283	0.0235	0.0212	0.0227	0.0241	0.0248
NMVOC emissions, kt	0.4378	0.4143	0.4247	0.3525	0.3186	0.3399	0.3615	0.3719
NO_x emissions, t/t	4.8639	4.6036	4.7193	3.9165	3.5395	3.7763	4.0172	4.1322
SO_2 emissions, kt	0.1459	0.1381	0.1416	0.1175	0.1062	0.1133	0.1205	0.1240
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Amount of ammonia produced, kt	3984.00	4541.20	4351.30	4500.00	4488.60	4674.40	4717.10	5217.50
Natural gas consumption of, mln m3	4809.0764	5387.3959	5138.8962	5297.4191	5254.5684	5491.3449	5483.1217	5862.7091
Carbon content in natural gas, t/TJ	15.18	15.18	15.18	15.18	15.18	15.18	15.18	15.19
Net calorific value of fuel combustion, TJ/mln m3	0.03340	0.03340	0.03340	0.03340	0.03340	0.03340	0.03340	0.03340
Stoichiometric ratio between CO_2 and C mol. weight	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667
Urea production, kt	2032.53	2468.96	2810.9	2809.8	2923.7	3154.71	3135.71	3234.62
Stoichiometric ratio of CO2 to urea	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733
CO_2 emission factor, t/t	1.870	1.807	1.722	1.731	1.699	1.690	1.674	1.636
CO emission factor, t/t	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006
NMVOC emission factor, t/t	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009
NO_x emission factor, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_2 emission factor, t/t	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
CO_2 emissions, kt	7451.609	8206.999	7494.389	7789.934	7626.695	7897.628	7896.272	8536.717
CO emissions, kt	0.0239	0.0272	0.0261	0.0270	0.0269	0.0280	0.0283	0.0313
NMVOC emissions, kt	0.3586	0.4087	0.3916	0.4050	0.4040	0.4207	0.4245	0.4696
NO_x emissions, t/t	3.9840	4.5412	4.3513	4.5000	4.4886	4.6744	4.7171	5.2175
SO_2 emissions, kt	0.1195	0.1362	0.1305	0.1350	0.1347	0.1402	0.1415	0.1565

Continuation of Table A3.1.1.5

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Amount of ammonia produced, kt	5152.20	5142.90	4892.00	3037.61	4166.12	5261.96	5049.41	4237.12	2983.93
Natural gas consumption of, mln m3	5747.9875	5627.3098	5412.8268	3530.1028	4724.4701	5876.5076	5661.0519	4677.6674	3225.9762
Carbon content in natural gas, t/TJ	15.22	15.16	15.17	15.2	15.17	15.12924	15.14023	15.16761	15.1214
Net calorific value of fuel combustion, TJ/mln m^3	0.03340	0.03340	0.03364	0.03340	0.03340	0.03396	0.03409	0.03413	0.03394
Stoichiometric ratio between CO_2 and C mol. weight	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667
Urea production, kt	3131.45	3169.54	2984.52	2767.469	2658.357	3389.308	3278.665	2619.888	2084.6
Stoichiometric ratio of CO_2 to urea	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733
CO_2 emission factor, t/t	1.634	1.580	1.623	1.496	1.639	1.632	1.646	1.642	1.522
CO emission factor, t/t	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006
NMVOC emission factor, t/t	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009
NO_x emission factor, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
SO_2 emission factor, t/t	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
CO_2 emissions, kt	8420.020	8125.778	7939.730	4543.600	6829.827	8585.973	8308.890	6957.837	4542.046
CO emissions, kt	0.0309	0.0309	0.0294	0.0182	0.0250	0.0316	0.0303	0.0254	0.0179
NMVOC emissions, kt	0.4637	0.4629	0.4403	0.2734	0.3750	0.4736	0.4544	0.3813	0.2686
NO_x emissions, t/t	5.1522	5.1429	4.8920	3.0376	4.1661	5.2620	5.0494	4.2371	2.9839
SO_2 emissions, kt	0.1546	0.1543	0.1468	0.0911	0.1250	0.1579	0.1515	0.1271	0.0895
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Amount of ammonia produced, kt	2640.647	2044.20	1191.02	976.475	1828.687	2806.462	2369.461		
Natural gas consumption of, mln m3	2779.1304	2152.89	1297.895	1008.994	1980.543	3102.085	2616.629		
Carbon content in natural gas, t/TJ	15.2137	15.260	15.202	15.225	15.273	15.210	15.210		
Net calorific value of fuel combustion, TJ/mln m3	0.03457	0.03453	0.03441	0.03453	0.034	0.034	0.034		
Stoichiometric ratio between CO2 and C mol. weight	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667		
Urea production, kt	2211.73	2152.8	1248.016	971.6	1904.562	2733.3	2180.8		
Stoichiometric ratio of CO2 to urea	0.7330	0.7330	0.7330	0.7330	0.733	0.733	0.733		
CO_2 emission factor, t/t	1.416	1.263	1.322	1.263	1.325	1.413	1.450		
CO emission factor, t/t	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006	0.000006		
NMVOC emission factor, t/t	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009		
NO_x emission factor, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
SO_2 emission factor, t/t	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003		
CO_2 emissions, kt	3740.106	2581.245	1575.079	1232.901	2423.909	3964.192	3435.265		
CO emissions, kt	0.0158	0.0123	0.0071	0.0059	0.011	0.017	0.014		
NMVOC emissions, kt	0.2377	0.1840	0.1072	0.088	0.165	0.253	0.213		
NO_x emissions, t/t	2.6406	2.0442	1.1910	0.976	1.829	2.806	2.369		
SO_2 emissions, kt	0.0792	0.0613	0.0357	0.029	0.055	0.084	0.071		

Table A3.1.1.6 Greenhouse gas emissions from Nitric Acid Production

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Nitric acid production, kt	2700.0	2386.8	2073.6	1760.4	1447.2	1134.0	1344.0	1471.0	1198.0	1295.0	1452.0
N_2O emission factor, t/t (Medium pressure units)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)
N_2O emission factor, t/t (Low pressure units)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)
NO_x emission factor, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O emissions, kt	12.442	11.004	9.533	8.032	6.644	5.191	6.195	6.740	5.557	5.972	6.768
NO_x emissions, kt	27.00	23.87	20.74	17.60	14.47	11.34	13.44	14.71	11.98	12.95	14.52
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Nitric acid production, kt	1407.0	1715.0	1726.0	1482.6	1757.4	1761.2	2294.5	2121.2	1451.8	1796.0	2309.5
N_2O emission factor, t/t (Medium pressure units)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.007 (D)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)
N_2O emission factor, t/t (Low pressure units)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)
NO_x emission factor, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O emissions, kt	6.557	7.923	7.913	6.888	8.124	8.161	10.561	9.744	6.599	8.048	10.57
NO_x emissions, kt	14.07	17.15	17.26	14.83	17.57	17.61	22.95	21.21	14.52	17.96	23.09
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	
Nitric acid production, kt	2337.0	1791.1	1569.4	1157.02	1399.8	1069.1	1011.2	1544.6	1679.38	1795.00	
N_2O emission factor, t/t (Medium pressure units)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	0.0045 (CS)	
N_2O emission factor, t/t (Low pressure units)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	0.005 (D)	
NO_x emission factor, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
N_2O emissions, kt	10.757	8.073	7.112	5.21	6.29	4.81	4.55	6.95	7.56	8.08	
NO_x emissions, kt	23.37	17.91	15.69	11.57	13.99	10.69	10.11	15.45	16.79	17.95	

Table A3.1.1.7 Greenhouse gas emissions from Adipic Acid Production

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Amount of adipic acid produced, kt	59.1	57.7	32.9	16.7	16.7	16	24.9	28.4	28.4	21.7	50.9	48.9	43.1	61.4	65.8	48.7
N_2O emission factor, t/t	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Thermal destruction factor	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.985
Thermal use factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
NO_x emission factor, t/t	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
NMVOC emission factor, t/t	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433
CO emission factor, t/t	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
N_2O emissions, kt	0.78987	0.77116	0.43971	0.22320	0.22320	0.21384	0.33279	0.37957	0.37957	0.29002	0.68028	0.65355	0.57603	0.82061	0.87942	0.650876
NO_x emissions, kt	0.4728	0.4616	0.2632	0.1336	0.1336	0.128	0.1992	0.2272	0.2272	0.1736	0.4072	0.3912	0.3448	0.4912	0.5264	0.3896
NMVOC emissions, kt	2.55903	2.49841	1.42457	0.72311	0.72311	0.6928	1.07817	1.22972	1.22972	0.93961	2.20397	2.11737	1.86623	2.65862	2.84914	2.10871
CO emissions, kt	0.02364	0.02308	0.01316	0.00668	0.00668	0.0064	0.00996	0.01136	0.01136	0.00868	0.02036	0.01956	0.01724	0.02456	0.02632	0.01948

Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Amount of adipic acid produced, kt	52.1	58.3	29.3	4.2	52.9	61.49	13.002									
N_2O emission factor, t/t	0.3	0.3	0.3	0.3	0.3	0.3	0.3									
Thermal destruction factor	0.985	0.985	0.985	0.985	0.985	0.985	0.985									
Thermal use factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97									
NO_x emission factor, t/t	0.008	0.008	0.008	0.008	0.008	0.008	0.008	Not produced								
NMVOC emission factor, t/t	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433	0.0433									
CO emission factor, t/t	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004									
N_2O emissions, kt	0.6963	0.7792	0.3916	0.0561	0.707	0.8218	0.1738									
NO_x emissions, kt	0.4168	0.4664	0.2344	0.0336	0.4232	0.4919	0.1040									
NMVOC emissions, kt	2.2559	2.5244	1.2687	0.1819	2.2906	2.6625	0.5630									
CO emissions, kt	0.0208	0.0233	0.0117	0.0017	0.0212	0.0246	0.0052									

Table A3.1.1.8 Greenhouse gas emissions from Petrochemical Production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO_2 emission factor for carbon black, t/t	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62
CO_2 emission factor for ethylene, t/t	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
Geographical correction factor for ethylene	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
CO_2 emission factor for methanol, t/t	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
CO_2 emission factor for vinyl chloride monomer, t/t	0.294	0.294	0.294	0.294	0.294	0.294	0.294	0.294	0.294	0.294
CH_4 emission factor for carbon black, t/t	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
CH_4 emission factor for ethylene, t/t	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
CH_4 emission factor for methanol, t/t	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
CH_4 emission factor for vinyl chloride monomer, t/t	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
SO_2 emission factor for carbon black, t/t	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
SO_2 emission factor for sulphuric acid, t/t	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905
NO_x emission factor for carbon black, t/t	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
NMVOC emission factor for carbon black, t/t	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
NMVOC emission factor for ethylene, t/t	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
NMVOC emission factor for vinyl chloride monomer, t/t	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
CO emission factor for carbon black, t/t	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NMVOC emission factor for polystyrene, t/t	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012
NMVOC emission factor for propylene, t/t	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
NMVOC emission factor for polyethylene, t/t	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
NMVOC emission factor for phthalic anhydride from naphthalene fraction, t/t	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
NMVOC emission factor for phthalic anhydride from o-xylene, t/t	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
NMVOC emission factor for polypropylene, t/t	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
NOx emissions for carbon black, kt	3.9	3.1635	2.35905	1.67715	0.9975	0.7725	0.7575	0.999	1.026	0.813
CO emissions for carbon black, kt	7.8	6.327	4.7181	3.3543	1.995	1.545	1.515	1.998	2.052	1.626
Total CO_2 emissions, kt	1962.330	1776.533	1378.781	920.161	1503.824	560.459	343.052	479.015	477.214	305.353
Total CH_4 emissions, kt	2.824	2.695	2.304	1.595	2.603	0.928	0.434	0.560	0.548	0.357
Total NMVOC emissions, kt	0.684	0.637	0.484	0.342	0.637	0.342	0.265	0.372	0.436	0.295
Total SO_2 emissions, kt	51.0695	42.5231	30.6099	19.1389	16.3593	15.5496	15.3828	14.4791	13.7585	13.7990

Continuation of Table A3.1.1.8

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2 emission factor for carbon black, t/t	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62
CO_2 emission factor for ethylene, t/t	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
Geographical correction factor for ethylene	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
CO_2 emission factor for methanol, t/t	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
CO_2 emission factor for vinyl chloride monomer, t/t	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
CH_4 emission factor for carbon black, t/t	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287
CH_4 emission factor for ethylene, t/t	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
CH_4 emission factor for methanol, t/t	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
CH_4 emission factor for vinyl chloride monomer, t/t	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
SO_2 emission factor for carbon black, t/t	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
SO_2 emission factor for sulphuric acid, t/t	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905
NO_x emission factor for carbon black, t/t	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
NMVOC emission factor for carbon black, t/t	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
NMVOC emission factor for ethylene, t/t	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
NMVOC emission factor for vinyl chloride monomer, t/t	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
CO emission factor for carbon black, t/t	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NMVOC emission factor for polystyrene, t/t	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012
NMVOC emission factor for propylene, t/t	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
NMVOC emission factor for polyethylene, t/t	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
NMVOC emission factor for phthalic anhydride from naphthalene fraction, t/t	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
NMVOC emission factor for phthalic anhydride from o-xylene, t/t	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
NMVOC emission factor for polypropylene, t/t	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
NOx emissions for carbon black, kt	0.645	1.071	0.8955	1.29	1.5015	1.7385	1.6035	1.8135	1.617	0.8805	1.1355
CO emissions for carbon black, kt	1.29	2.142	1.791	2.58	3.003	3.477	3.207	3.627	3.234	1.761	2.271
Total CO_2 emissions, kt	317.422	442.359	679.86	786.38	899.97	866.65	917.15	919.37	579.81	216.98	334.74
Total CH_4 emissions, kt	0.461	29.485	57.684	82.408	112.050	90.440	85.382	81.600	33.905	0.220	14.968
Total NMVOC emissions, kt	0.294	0.739	1.131	1.291	1.579	1.388	1.402	1.442	0.813	0.446	0.599
Total SO_2 emissions, kt	10.3218	10.9828	9.7751	12.145	15.098	17.084	15.863	17.655	15.756	9.3459	13.39

Continuation of Table A3.1.1.8

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2 emission factor for carbon black, t/t	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62
CO_2 emission factor for ethylene, t/t	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
Geographical correction factor for ethylene	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
CO_2 emission factor for methanol, t/t	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
CO_2 emission factor for vinyl chloride monomer, t/t	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
CH_4 emission factor for carbon black, t/t	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287	0.0287
CH_4 emission factor for ethylene, t/t	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
CH_4 emission factor for methanol, t/t	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
CH_4 emission factor for vinyl chloride monomer, t/t	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
SO_2 emission factor for carbon black, t/t	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
SO_2 emission factor for sulphuric acid, t/t	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905	0.00905
NO_x emission factor for carbon black, t/t	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
NMVOC emission factor for carbon black, t/t	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
NMVOC emission factor for ethylene, t/t	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
NMVOC emission factor for vinyl chloride monomer, t/t	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
CO emission factor for carbon black, t/t	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NMVOC emission factor for polystyrene, t/t	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012	0.00012
NMVOC emission factor for propylene, t/t	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
NMVOC emission factor for polyethylene, t/t	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023
NMVOC emission factor for phthalic anhydride from naphthalene fraction, t/t	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
NMVOC emission factor for phthalic anhydride from o-xylene, t/t	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
NMVOC emission factor for polypropylene, t/t	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
NOx emissions for carbon black, kt	0.8803	1.2898	1.1775	1.0561	0.8280	1.081	1.161	1.341	1.319	1.265	1.437
CO emissions for carbon black, kt	1.7606	2.5797	2.355	2.1123	1.6560	2.162	2.321	2.683	2.638	2.529	2.874
Total CO_2 emissions, kt	657.90	606.76	236.35	199.73	144.62	188.88	411.147	666.299	709.284	675.728	784.18
Total CH_4 emissions, kt	72.241	56.545	6.310	0.057	0.00331	0.004	37.622	100.196	114.505	117.636	134.221
Total NMVOC emissions, kt	1.263	0.787	0.116	0.050	0.0389	0.051	0.495	1.041	1.15	1.11	1.31
Total SO_2 emissions, kt	15.198	14.280	12.330	6.7526	5.7986	6.326	6.783	8.117	8.105	8.039	9.18

Table A3.1.1.9 Greenhouse gas emissions from Steel Production (CRF category 2.C.1.1)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Steel production, kt	52635.4	44994.5	41759.2	32609.7	24081.2	22307.9	22332.9	25628.5	24446.5	27392.2	31781.0	33522.1	34546.4	37524.1	38718.5	38615.5
Specific pig iron consumption for steel production, t/t	0.671	0.681	0.693	0.706	0.726	0.724	0.730	0.741	0.739	0.744	0.742	0.746	0.729	0.744	0.759	0.769
Specific scrap consumption for steel production, t/t	0.367	0.370	0.372	0.372	0.355	0.357	0.351	0.342	0.343	0.339	0.340	0.336	0.338	0.337	0.328	0.330
Carbon content in steel, %	0.218	0.219	0.219	0.219	0.216	0.217	0.216	0.215	0.215	0.214	0.214	0.214	0.214	0.214	0.213	0.213
CO_2 emission factor, t/t	0.103	0.106	0.109	0.109	0.114	0.115	0.114	0.112	0.111	0.112	0.112	0.113	0.112	0.115	0.117	0.122
CO_2 emissions, kt	5417.9	4777.2	4536.2	3569.7	2753.3	2559.5	2556.8	2864.8	2706.0	3080.5	3553.6	3795.1	3879.3	4314.0	4547.5	4711.3
NO_x emissions, kt	0.69	0.61	0.58	0.46	0.29	0.26	0.26	0.27	0.27	0.28	0.31	0.32	0.35	0.39	0.37	0.38
CO emissions, kt	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07
NMVOC emissions, kt	0.72	0.63	0.59	0.45	0.30	0.29	0.28	0.30	0.29	0.32	0.37	0.38	0.39	0.43	0.41	0.41
SO_2 emissions, kt	0.2200	0.1999	0.1920	0.1494	0.0856	0.0761	0.0729	0.0703	0.0697	0.0680	0.0774	0.0739	0.0857	0.0957	0.0795	0.0830
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Steel production, kt	40891.8	42828.5	37082.3	29848.0	32681.8	34762.0	32497.9	32673.0	27144.1	22997.6	24196.0	21049.3	20994.5	20848.0	20616.0	21366.0
Specific pig iron consumption for steel production, t/t	0.775	0.772	0.789	0.805	0.794	0.776	0.803	0.819	0.823	0.842	0.847	0.810	0.816	0.806	0.839	0.836
Specific scrap consumption for steel production, t/t	0.329	0.323	0.328	0.297	0.297	0.329	0.301	0.288	0.282	0.263	0.253	0.286	0.286	0.263	0.263	0.268
Carbon content in steel, %	0.213	0.213	0.213	0.210	0.212	0.212	0.210	0.211	0.211	0.210	0.210	0.213	0.213	0.210	0.210	0.210
CO_2 emission factor, t/t	0.123	0.122	0.125	0.128	0.126	0.123	0.127	0.125	0.128	0.133	0.136	0.130	0.129	0.128	0.134	0.133
CO_2 emissions, kt	5028.0	5244.0	4646.4	3816.4	4119.4	4286.5	4142.9	4068.1	3482.9	3066.4	3279.9	2739.6	2702.09	2675.62	2759.75	2844.38
NO_x emissions, kt	0.41	0.43	0.41	0.38	0.44	0.52	0.44	0.49	0.42	0.32	0.34	0.35	0.35	0.28	0.3	0.32
CO emissions, kt	0.08	0.08	0.07	0.07	0.08	0.09	0.09	0.09	0.07	0.06	0.07	0.05	0.05	0.05	0.06	0.06
NMVOC emissions, kt	0.43	0.46	0.38	0.22	0.27	0.27	0.21	0.22	0.19	0.16	0.15	0.17	0.17	0.15	0.13	0.13
SO_2 emissions, kt	0.0900	0.0980	0.0942	0.0803	0.1048	0.1280	0.0922	0.1162	0.0999	0.0732	0.0732	0.0957	0.0950	0.0608	0.0658	0.0744

Table A3.1.1.10 Greenhouse gas emissions from Iron Production (CRF category 2.C.1.2)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Iron production, kt	44927.4	36632.1	35350.0	27108.0	20180.3	17998.4	17831.5
Sinter production, kt	60926.5	51109.2	49473.2	40110.8	30376.8	26277.9	25817.8
Carbon content in iron, %	4.37	4.43	4.45	4.40	4.40	4.50	4.45
Carbon content in iron, kt	1963.33	1622.80	1573.08	1192.75	887.93	809.93	793.50
Use of coke for iron production, kt	23586.9	19653.1	19152.6	15766	12927.5	11400.9	11140.2
Carbon content in coke, %	85.29	85.23	85.17	85.11	85.05	84.99	84.94
Use of coal for iron production, kt	0.00	0.00	0.00	0.00	0.00	47.50	34.60
Carbon content in coal, %	0.00	0.00	0.00	0.00	0.00	71.95	71.95
Use of natural gas for iron production, mln m^3	5.55	5.32	5.10	4.89	4.69	4.49	4.30
CO_2 emission factor when natural gas is used, t $CO_2/10^3$ m^3	1.856	1.858	1.859	1.859	1.859	1.859	1.859
CO_2 emission factor at iron production, t/t	1.48	1.51	1.53	1.65	1.84	1.82	1.79
CO_2 emissions, kt	66 571.30	55 476.08	54 052.49	44 837.20	37 068.79	32 694.22	31 883.92
Emissions of CH_4 (iron), kt	40.43466	32.96889	31.815	24.3972	18.16227	16.19856	16.04835
Emissions of CH_4 (sinter), kt	4.64819	3.78996	3.65731	2.80459	2.08785	1.85715	1.82231
NO_x emissions, kt	3.414482	2.784039	2.6866	2.06020	1.533702	1.3678784	1.355194
CO emissions, kt	58.40562	47.62173	45.955	35.2404	26.23439	23.39792	23.18095
NMVOC emissions, kt	4.49274	3.66321	3.535	2.7108	2.01803	1.79984	1.78315
SO_2 emissions, kt	89.8548	73.2642	70.7	54.216	40.3606	35.9968	35.663
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Iron production, kt	20616.0	20936.7	23009.8	25698.7	26378.5	27633.3	29529.0
Sinter production, kt	29573.9	31539.0	35781.7	38801.3	41287.9	42991.6	44935.6
Carbon content in iron, %	4.29	4.26	4.30	4.29	4.32	4.38	4.39
Carbon content in iron, kt	884.43	891.90	989.42	1102.47	1139.55	1210.34	1296.32
Use of coke for iron production, kt	12562.2	12201.6	12825.9	14108.1	14737.5	15196.6	15405.9
Carbon content in coke, %	84.88	84.82	84.76	84.76	84.8	84.94	84.85
Use of coal for iron production, kt	19.50	49.70	52.00	46.30	47.7	31.10	66.10
Carbon content in coal, %	71.95	71.95	71.95	71.78	72.3	74.93	75.72
Use of natural gas for iron production, mln m3	4.12	3.95	3.79	3.63	3.48	3.33	3.41
CO_2 emission factor when natural gas is used, t $CO_2/10^3$ m^3	1.859	1.859	1.859	1.859	1.859	1.859	1.859
CO_2 emission factor at iron production, t/t	1.74	1.66	1.58	1.55	1.58	1.56	1.47
CO_2 emissions, kt	35 912.21	34 815.50	36 378.01	39 932.81	41 804.30	42 980.81	43 365.86
Emissions of CH_4 (iron), kt	18.5544	18.84303	20.70882	23.12883	23.740	24.8699	26.5761
Emissions of CH_4 (sinter), kt	2.16334	2.27654	2.57550	2.84505	2.99613	3.10714	3.14549
NO_x emissions, kt	1.566816	1.5911892	1.7487448	1.9531012	2.0047	2.10013	2.2442
CO emissions, kt	26.8008	27.21771	29.91274	33.40831	34.292	35.92329	38.3877
NMVOC emissions, kt	2.0616	2.09367	2.30098	2.56987	2.6378	2.76333	2.9529
SO_2 emissions, kt	41.232	41.8734	46.0196	51.3974	52.3974	55.2666	59.058

Continuation of Table A3.1.1.10

Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Iron production, kt	30977.6	30746.1	32929.3	35649.7	30991.3	25683.1	27365.8	28877.0	28486.6
Sinter production, kt	48134.0	48582.8	49002.8	51216.8	44553.1	35863.3	39492.6	40219.6	42598.0
Carbon content in iron, %	4.40	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Carbon content in iron, kt	1363.01	1383.57	1481.82	1604.24	1394.61	1155.74	1231.46	1299.46	1281.89
Use of coke for iron production, kt	15669.4	14955.8	16235.4	17713.4	17884.10	15624.0	15990.821	16126.92	15661.86
Carbon content in coke, %	84.59	84.94	85.02	84.85	84.94	84.85	84.85	85.2	85.3
Use of coal for iron production, kt	115.40	161.90	140.40	170.70	101.97	126.66	151.20	154.20	139.28
Carbon content in coal, %	77.73	78.34	78.95	79.57	80.18	80.79	80.44	79.8	80.5
Use of natural gas for iron production, mln m3	3.47	3.47	2.89	2.64	1.899	1.67	1.57	1.896	1.757
CO_2 emission factor when natural gas is used, t $CO_2/10^3$ m^3	1.859	1.861	1.864	1.857	1.871	1.862	1.858	1.884	1.892
CO_2 emission factor at iron production, t/t	1.42	1.37	1.38	1.39	1.64	1.74	1.67	1.60	1.57
CO_2 emissions, kt	43 938.37	41 977.75	45 590.73	49 730.07	50 889.22	44 749.38	45 683.63	46 076.53	44 721.57
Emissions of CH_4 (iron), kt	27.8798	27.6715	29.6364	32.08473	27.89217	23.11479	24.62922	25.9893	25.63794
Emissions of CH_4 (sinter), kt	3.36938	3.40080	3.43020	3.58518	3.11872	2.51043	2.76448	2.81537	2.98186
NO_x emissions, kt	2.35429	2.33670	2.50262	2.70937	2.35533	1.951915	2.0798008	2.194652	2.1649816
CO emissions, kt	40.2709	39.9699	42.8081	46.34461	40.28869	33.38803	35.57554	37.5401	37.03258
NMVOC emissions, kt	3.09776	3.07461	3.29293	3.56497	3.09913	2.56831	2.73658	2.8877	2.84866
SO_2 emissions, kt	61.9552	61.4922	65.8586	71.2994	61.9826	51.3662	54.7316	57.754	56.9732
Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Iron production, kt	29088.7	24800.9	21862.8	23559.5	20116.5	20531.2	20055.9	20238.0	21165.0
Sinter production, kt	43624	38294.601	33575.718	34383	31000	31680	30911	31907	32917
Carbon content in iron, %	4.31	4.42	4.49	4.54	4.55	4.47	4.52	4.52	4.51
Carbon content in iron, kt	1254.45	1096.7	981.26	1068.78	914.73	917.62	906.28	914.83	954.61
Use of coke for iron production, kt	15456.933	13417.59	12536.7	12872.72	11342.36	11897.95	11014.83	10296.62	10667.31
Carbon content in coke, %	84.8	84.2	84.2	84.9	84.3	84.9	87.9	87.0	86.3
Use of coal for iron production, kt	117.75	110.01	91.30	108.79	111.18	142.04	166.63	94.42	97.82
Carbon content in coal, %	77.9	76.3	79.6	79.6	78.99	77.6	77.52	77.62	79.96
Use of natural gas for iron production, mln m3	1.701	3.4487	1.54	1.35	1.13	1.35	1.02	1.45	1.5
CO_2 emission factor when natural gas is used, t $CO_2/10^3$ m^3	1.898	1.882	1.929	1.932	1.918	1.928	1.929	1.924	1924
CO_2 emission factor at iron production, t/t	1.51	1.52	1.62	1.55	1.59	1.66	1.63	1.47	1.44
CO_2 emissions, kt	43 820.08	37 732.41	35 357.66	36 466.72	32 018.22	34 069.27	32 637.35	29 780.22	30561.05
Emissions of CH_4 (iron), kt	26.17983	22.32081	19.676	21.203	18.105	18.478	18.05	18.21	19.05
Emissions of CH_4 (sinter), kt	3.05368	2.68062	2.35030	2.407	2.17	2.22	2.16	2.23	2.3
NO_x emissions, kt	2.2107412	1.8848684	1.6615	1.790	1.529	1.56	1.52	1.54	1.61
CO emissions, kt	37.81531	32.24117	28.42164	30.627	26.151	26.69	26.07	26.31	27.51
NMVOC emissions, kt	2.90887	2.48009	2.18628	2.356	2.012	2.053	2.001	2.024	2.12
SO_2 emissions, kt	58.1774	49.6018	43.7256	47.119	40.233	41.06	40.11	40.48	42.33

Table A3.1.1.11 Greenhouse gas emissions from Ferroalloys Production (CRF category 2.C.2)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Ferroalloys Production, kt	2135.5	1930.1	1026.5	1026.5	1026.5	1026.5	1026.5	1026.5	851.6	934.5	1279.7	1296.3	1288.3	1490.0	1912.3	1632.4
CO_2 emission factor, t/t	1.646	1.64	1.73	1.71	1.77	1.78	1.73	1.76	1.79	1.73	1.78	1.79	1.69	1.63	1.59	1.60
CH_4 emission factor, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CO_2 emissions, kt	3515.98	3166.71	1775.44	1752.28	1812.80	1825.96	1774.47	1810.94	1521.35	1613.09	2281.50	2325.00	2173.34	2435.12	3043.30	2608.87
CH_4 emissions, kt	0.605	0.533	0.422	0.345	0.243	0.264	0.216	0.246	0.196	0.215	0.287	0.302	0.308	0.244	0.242	0.157
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Ferroalloys Production, kt	1709.6	1867.9	1662.8	1200.7	1671.3	1419.6	1300	1142.22	1362.47	1092.13	1218.32	1278.99	1244.79	1183.93	853.67	1017.8
CO_2 emission factor, t/t	1.61	1.69	1.71	1.61	1.68	1.60	1.64	1.67	1.76	1.73	1.62	1.51	1.56	1.55	1.52	1.57
CH_4 emission factor, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
CO_2 emissions, kt	2755.29	3164.35	2849.91	1938.97	2801.74	2264.65	2132.67	1909.01	2396.61	1894.23	1972.62	1925.81	1947.03	1839.1	1301.78	1600.01
CH_4 emissions, kt	0.122	0.167	0.154	0.159	0.155	0.111	0.089	0.152	0.132	0.093	0.105	0.096	0.076	0.064	0.060	0.092

Table A3.1.1.12 Greenhouse gas emissions from Aluminium Production (CRF category 2.C.3)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
CO_2 emissions, kt	170.28	163.44	158.04	159.84	153.72	153.18	150.48	163.26	168.48	177.30	178.02	186.30	190.44	193.50	195.84	201.60
CF_4 emissions, kt	0.0274	0.0219	0.0165	0.0167	0.0187	0.0207	0.0166	0.0171	0.0140	0.0118	0.0134	0.0130	0.0115	0.0090	0.0108	0.0165
C_2F_6 emissions, kt	0.0027	0.0022	0.0017	0.0017	0.0019	0.0021	0.0017	0.0017	0.0014	0.0012	0.0013	0.0013	0.0011	0.0009	0.0011	0.0017
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
CO_2 emissions, kt	200.16	201.89	200.79	89.38	44.84	Not producted										
CF_4 emissions, kt	0.0129	0.0180	0.0202	0.0063	0.0031											
C_2F_6 emissions, kt	0.0013	0.0018	0.0020	0.0006	0.0003											

Table A3.1.1.13 Greenhouse gas emissions from Lubricant Use

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total consumption, TJ	20783.40	20783.40	15597.60	12904.20	9969.60	9125.40	19336.20	22793.40	16080.00	12341.40	11617.80	12622.80	12140.4	10452.0	6311.40	9447.00
Carbon content, t C/TJ	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Oxydation factor at use, t/t	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Stoichiometric ratio between CO_2 and C mol. weight	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667
Emissions of CO_2, kt	304.826	304.826	228.767	189.263	146.222	133.840	283.600	334.306	235.842	181.009	170.396	185.136	178.06	153.3	92.568	138.56
CO_2 emission factor, t/t	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total consumption, TJ	7718.40	13386.60	12904.20	10050.00	11939.40	10452.00	10090.20	9527.40	8770.39	8132.52	7965.7	9216.85	10426.3	8966.62	9058.37	8915.59
Carbon content, t C/TJ	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Oxydation factor at use, t/t	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Stoichiometric ratio between CO_2 and C mol. weight	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667	3.667
Emissions of CO_2, kt	113.204	196.339	189.263	147.401	175.113	153.297	147.991	139.736	128.634	119.28	116.83	135.18	152.92	131.51	132.86	130.76
CO_2 emission factor, t/t	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0.590	0590

Table A3.1.1.14 Greenhouse gas emissions from Paraffin Wax Use

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total consumption, TJ	8375.5	8354.4	4648.1	1708.5	1068.5	970.02	365.22	119.08	72.88	84.08	733.80	633.24	736.04	743.67	707.67	634.32
Carbon content, t C/TJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Oxydation factor at use, t/t	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Stoichiometric ratio between CO_2 and C mol. weight	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667
Emissions of CO_2, kt	122.84	122.53	68.173	25.058	15.671	14.227	5.357	1.746	1.069	1.233	10.763	9.288	10.795	10.907	10.379	9.303
CO_2 emission factor, t/t	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Total consumption, TJ	628.44	597.17	610.29	266.23	722.76	674.39	737.23	781.63	829.32	716.49	703.22	629.68	697.03	726.9	712.98	710.09
Carbon content, t C/TJ	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Oxydation factor at use, t/t	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Stoichiometric ratio between CO_2 and C mol. weight	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667
Emissions of CO_2, kt	9.217	8.758	8.951	3.905	10.601	9.891	9.891	11.464	12.163	10.509	10.314	9.235	10.223	10.661	10.457	10.415
CO_2 emission factor, t/t	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896	0.5896

Table A3.1.1.15 Greenhouse gas emissions from product uses as substitutes for ozone-depleting substances

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Domestic refrigeration, kt CO_{2-eq}				2.330	12.978	19.504	25.785	27.995	32.476	36.445	43.286	23.947	15.735
Comercial refrigeration, kt CO_{2-eq}				4.459	0.310	10.584	21.750	33.802	46.634	57.435	64.360	67.802	68.124
Industrial refrigeration, kt CO_{2-eq}					1.271	5.948	8.697	19.248	36.913	77.846	122.819	146.503	158.043
Transport refrigeration, kt CO_{2-eq}				0.185	0.380	0.470	0.883	1.758	2.493	3.456	2.685	5.667	3.958
Comercial air conditioning, kt CO_{2-eq}						0.034	0.125	0.182	0.544	1.110	4.227	11.721	13.392
Industrial air conditioning, kt CO_{2-eq}													
Mobile air conditioning for automotive vehicles, kt CO_{2-eq}		0.512	0.855	1.742	4.730	9.578	17.288	33.561	43.545	61.870	101.722	154.855	152.428
Mobile air conditioning for railway transport, kt CO_{2-eq}				0.013	0.028	0.095	0.184	0.280	0.304	0.422	0.471	0.723	0.642
OPF, kt CO_{2-eq}						3.575	9.295	40.040	84.370	104.390	128.70	130.13	130.13
RPUF, kt CO_{2-eq}						0.00389	0.00778	0.02048	0.03604	0.04914	0.07351	0.10726	0.14187
RPUF (insulation by spraying, pouring, injection), kt CO_{2-eq}						0.1369	3.0398	4.7531	0.4368	6.0817	14.186	11.5509	7.77503
XPS, kt CO_{2-eq}						0.4032	0.8022	1.806	3.093	4.525	6.67095	8.88459	9.50235
Fire protection, kt CO_{2-eq}						0.215	0.704	1.124	2.027	6.937	8.968	12.237	15.272
Aerosols use, kt CO_{2-eq}	6.431	12.507	13.288	11.461	9.350	13.661	16.517	21.940	30.588	41.709	62.958	73.121	88.620
Total HFCs emissions, kt CO_{2-eq}	6.43	13.02	14.14	15.73	29.05	64.27	105.20	187.26	285.07	402.28	561.13	647.25	663.76
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	
Domestic refrigeration, kt CO_{2-eq}	15.849	14.196	15.103	15.876	14.671	5.863	6.093	9.23	31.10	110.2	91.86	115.35	
Comercial refrigeration, kt CO_{2-eq}	70.364	73.209	76.950	78.296	76.069	75.825	131.686	147.358	209.545	268.63	273.68	270.03	
Industrial refrigeration, kt CO_{2-eq}	147.479	75.862	59.237	46.653	34.302	28.884	26.289	24.964	26.382	24.338	22.286	21.240	
Transport refrigeration, kt CO_{2-eq}	4.883	8.186	11.231	11.629	10.649	7.098	6.255	13.278	18.683	17.634	14.608	8.784	
Comercial air conditioning, kt CO_{2-eq}	17.251	67.390	109.230	148.817	181.097	219.248	266.789	331.841	513.958	641.106	699.48	793.005	
Industrial air conditioning, kt CO_{2-eq}	42.722	124.993	136.416	136.768	130.541	127.739	130.291	138.797	177.384	195.902	191.93	186.63	
Mobile air conditioning for automotive vehicles, kt CO_{2-eq}	150.672	155.619	166.974	167.584	154.503	143.918	123.457	112.112	107.644	106.305	105.591	133.59	
Mobile air conditioning for railway transport, kt CO_{2-eq}	0.679	0.716	0.677	0.500	0.460	0.432	0.434	0.426	0.374	0.351	0.335	0.331	
OPF, kt CO_{2-eq}	108.68	38.61	40.04	38.839	35.149	28.049	35.061	39.970	48.363	53.452	63.074	73.607	
RPUF, kt CO_{2-eq}	0.18363	1.8007	2.0899	2.4313	2.232	1.836	2.246	2.537	3.027	3.33	3.89	4.50	
RPUF (insulation by spraying, pouring, injection), kt CO_{2-eq}	34.2449	44.1896	18.6981	28.2897	27.322	24.253	29.076	32.90	38.876	43.199	50.278	58.17	
XPS, kt CO_{2-eq}	9.867	15.72	11.83	18.508	29.055	31.092	36.318	40.436	44.078	47.158	52.599	56.283	
Fire protection, kt CO_{2-eq}	17.698	19.058	21.056	25.631	28.996	31.116	34.452	36.838	41.78	48.00	53.14	59.40	
Aerosols use, kt CO_{2-eq}	123.288	183.618	174.764	171.885	144.054	76.298	92.926	118.596	134.631	125.396	128.74	120.07	
Total HFCs emissions, kt CO_{2-eq}	743.86	823.17	844.29	891.71	869.10	801.65	921.37	1049.28	1395.83	1685.00	1751.50	1901.02	

Table A3.1.1.16 GHG emissions from use of sulfur hexafluoride

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Amount of sulfur hexafluoride in the produced equipment, t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.103	0.339	1.427	2.323	1.606
Amount of sulfur hexafluoride in the installed equipment, t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.60	1.72	1.01	0.50	0.69
Amount of sulfur hexafluoride in the exploited equipment, t	0.07	0.17	0.27	0.52	0.57	0.59	0.62	1.12	1.70	2.69	3.02	3.39	5.95	7.17	8.67	13.91	18.66
Leaks in production of the equipment,%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Leaks in installation of the equipment,%	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaks in exploitation of the equipment,%	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Emissions from production of the equipment, kt CO_2-eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.114	0.391	1.763	2.652	1.831
Emissions from installation of the equipment, kt CO_2-eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0763	0.0763	0.276	0.782	0.457	0.229	0.314
Emissions from production and installation of the equipment, kt CO_2-eq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.763	0.0763	0.391	1.173	2.089	2.881	2.146
Emissions from exploitation of the equipment, kt CO_2-eq	0.0076	0.019	0.0305	0.0591	0.0648	0.0677	0.0696	0.127	0.193	0.307	0.344	0.386	0.678	0.817	0.988	1.586	2.127
Total emissions, tons of CO_2-eq	0.0076	0.0191	0.0305	0.0591	0.0649	0.0677	0.0696	0.1278	0.1937	0.3072	0.4205	0.4632	1.0695	1.9912	3.078	4.4671	4.274

Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**		
Amount of sulfur hexafluoride in the produced equipment, t	1.375	3.191	2.590	2.620	3.49	4.820	2.052	6.647	2.397	2.438	1.429	3.808	6.478	1.005	1.007		
Amount of sulfur hexafluoride in the installed equipment, t	2.09	3.03	2.36	1.65	0.238	0.177	0.124	0.168	0.165	0.167	0.105	0.236	0.422	0.527	0.525		
Amount of sulfur hexafluoride in the exploited equipment, t	23.51	37.90	46.76	52.37	69.386	90.872	107.48	139.4	169.24	210.68	248.65	288.63	332.09	377.15	426.21		
Leaks in production of the equipment,%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5		
Leaks in installation of the equipment,%	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		
Leaks in exploitation of the equipment,%	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500		
Emissions from production of the equipment, kt CO_2-eq	1.564	3.634	2.957	2.985	0.397	0.5495	0.2339	0.758	0.273	0.278	0.163	0.434	0.738	0.115	0115		
Emissions from installation of the equipment, kt CO_2-eq	0.953	1.383	1.077	0.753	0.108	0.0807	0.0565	0.0765	0.0753	0.0761	0.048	0.107	0.193	0.240	0.240		
Emissions from production and installation of the equipment, kt CO_2-eq	2.518	5.017	4.035	3.739	0.506	0.6032	0.2905	0.834	0.348	0.354	0.211	0.541	0.931	0.355	0.354		
Emissions from exploitation of the equipment, kt CO_2-eq	2.679	4.320	5.330	5.970	7.91	10.359	12.253	15.891	19.294	24.017	28.346	32.904	37.858	42.995	48.588		
Total emissions, t CO_2-eq	5.1982	9.3381	9.3656	9.7100	8.414	10.99	12.5431	16.726	19.642	24.372	28.557	33.445	38.789	43.350	48.942		

Table A3.1.1.17 Greenhouse gas emissions from Food and Beverages Industry

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Amount of meat and fish produced, kt	5419	4850	4079	3485	3089	2694	2558	2422	2286	2149	2013
Amount of margarine produced, kt	289	267	249	173	106	109	89,2	84,7	96,8	120	162
Amount of mixed fodder produced, kt	1647	1454	1132	9730	7957	6439	4139	2226	2020	1757	1126
Amount of bakery products produced, kt	6701	6685	6441	5444	4816	4114	3452	3060	2672	2510	2464
Amount of confectionery products produced, kt	436	398	336	275	185	130	103	117	146	188	237
Amount of sugar produced, kt	6791	4786	3647	3993	3368	3894	3296	2034	1984	1858	1780
Amount of cognac and brandy produced, 10^3 hl	110	105	82	75	57	58	90	96	79	108	157
Amount of vodka produced, 10^3 hl	3087	3360	3675	4029	3630	3748	2478	2707	2161	2316	2008
Amount of wine produced, 10^3 hl	2723	2656	2089	1438	1156	1381	1199	990	771	856	948
Amount of beer produced, 10^3 hl	13778	13093	10997	9086	9087	7102	6025	6125	6842	8407	10765
Emission factor for meat and fish, t/t	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Emission factor for margarine, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emission factor for mixed fodder, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission factor for bakery products, t/t	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Emission factor for confectionery products, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission factor for sugar, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emission factor for cognac and brandy, kg/hl	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
Emission factor for vodka, kg/hl	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075
Emission factor for wine, kg/hl	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Emission factor for beer, kg/hl	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035
Total NMVOC emissions from food production, kt	104.663	83.920	70.636	77.209	65.481	65.920	54.395	38.027	35.684	33.665	32.475
Total NMVOC emissions from beverage production, kt	24.238	26.238	28.402	30.913	27.835	28.672	19.207	20.932	16.785	18.111	16.062
Total food and beverages, kt	128.901	110.158	99.038	108.122	93.316	94.592	73.602	58.959	52.469	51.775	48.537

Continuation of Table A3.1.1.17

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Amount of meat and fish produced, kt	1850	1941	1973	1826	1863	1952	581	689	806	825
Amount of margarine produced, kt	198	203	250	282	302	311	317	316	353	363
Amount of mixed fodder produced, kt	1262	1827	3341	3287	4161	4817	4949	5125	5867	6090
Amount of bakery products produced, kt	2450	2358	2335	2307	2264	2160	2034	1978	1828	1808
Amount of confectionery products produced, kt	269	310	359	367	411	446	473	499	453	482
Amount of sugar produced, kt	1947	1621	2486	2147	2139	2592	1867	1571	1275	1805
Amount of cognac and brandy produced, 10^3 hl	141	147	163	200	240	277	358	389	313	358
Amount of vodka produced, 10^3 hl	2205	2378	2671	4029	3506	3549	3721	3805	4033	4075
Amount of wine produced, 10^3 hl	1425	2081	1531	1541	1643	1710	1947	2105	2310	2966
Amount of beer produced, 10^3 hl	13059	15000	17012	19373	23805	26750	31579	32039	30005	30656
Emission factor for meat and fish, t/t	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Emission factor for margarine, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emission factor for mixed fodder, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission factor for bakery products, t/t	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Emission factor for confectionery products, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission factor for sugar, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emission factor for cognac and brandy, kg/hl	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
Emission factor for vodka, kg/hl	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075
Emission factor for wine, kg/hl	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Emission factor for beer, kg/hl	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035
Total NMVOC emissions from food production, kt	34.561	31.570	42.159	38.873	39.729	44.599	36.589	33.602	31.068	36.636
Total NMVOC emissions from beverage production, kt	17.602	19.041	21.321	31.719	28.100	28.660	30.422	31.189	32.578	33.126
Total food and beverages, kt	52.163	50.611	63.480	70.592	67.829	73.259	67.011	64.790	63.646	69.761

Continuation of Table A3.1.1.17

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Amount of meat and fish produced, kt	864	892	1049	1048	1303.470	1181.639	1655.502	1867.217	1930.804	1593.334	1795.273
Amount of margarine produced, kt	359	328	283	271	192.897	187.874	230.070	223.037	247.551	233.307	241.713
Amount of mixed fodder produced, kt	6199	6401	6816	6919	7063.166	7019.592	6882.645	6952.156	7279.585	7009.840	6245.725
Amount of bakery products produced, kt	1763	1686	1561	1357	1381.975	1301.210	1203.619	1093.689	1001.371	891.441	857.205
Amount of confectionery products produced, kt	489	392	388	331	312.525	267.904	430.176	447.599	458.053	529.839	590.850
Amount of sugar produced, kt	2586	2143	1263	2583	1766.840	2435.877	3058.039	2682.440	1796.047	1231.875	1706.876
Amount of cognac and brandy produced, 10^3 hl	471	461	455	261	369.231	348.097	302.098	282.207	319.951	253.792	248.029
Amount of vodka produced, 10^3 hl	3335	3384	2805	2147	1865.233	1664.562	1371.583	1281.282	1096.063	1165.556	1276.401
Amount of wine produced, 10^3 hl	1687	1276	1167	719	1018.776	929.072	959.828	1034.153	943.553	775.679	995.107
Amount of beer produced, 10^3 hl	30297	29674	27397	24224	20284.358	18825.659	18693.428	18933.942	18912.598	18827.741	17681.657
Emission factor for meat and fish, t/t	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Emission factor for margarine, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emission factor for mixed fodder, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission factor for bakery products, t/t	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045
Emission factor for confectionery products, t/t	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Emission factor for sugar, t/t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Emission factor for cognac and brandy, kg/hl	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
Emission factor for vodka, kg/hl	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075	0.0075
Emission factor for wine, kg/hl	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Emission factor for beer, kg/hl	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035	0.000035
Total NMVOC emissions from food production, kt	44.335	39.362	30.007	42.215	33.58	39.735	46.107	41.936	33.259	26.681	30.718
Total NMVOC emissions from beverage production, kt	27.856	28.134	23.682	17.921	16.07	14.436	12.075	11.343	10.078	10.351	11.140
Total food and beverages, kt	72.191	67.496	53.689	60.137	49.66	54.171	58.182	53.279	43.337	37.032	41.858

A3.1.2 Determination of the amount of limestone and dolomite use

Limestone and dolomite are widely used in manufacture of various products. Statistical data of limestone and dolomite use in Ukraine are not available. SSSU [2] provides data only of production of fluxing limestone.

CO_2 emissions from limestone and dolomite use are accounted in the categories in which they are used.

To estimate CO_2 emissions from use of limestone and dolomite, in the previous NIR data on application of fluxing limestone were used taking into account export and import of limestone and with formation of the estimated balance of limestone use for production of all types of products. However, researches have shown that fluxing limestone is also used for lime and other products production. Therefore, the definition of activity data in this category based on statistical data on fluxing limestone manufacturing resulted in overestimation of CO_2 emissions. In 2012, the State Enterprise SE "UkrRTC "Energostal" performed the scientific-research work "Development of methods for calculation and determination of carbon dioxide emissions from limestone and dolomite use" [8], aimed at determining activity data and national CO_2 emission factors. To determine amounts of limestone used, this scientific-research work used statistics of sinter, pellets, pig iron, steel, and ferroalloys production, as well as industry limestone and dolomite consumption rates in production of these types of products. Table A3.1.2.1 shows results of estimation of the amount of limestone and dolomite used in the metallurgy in 2021 obtained using this scientific-research work, as well as results of estimation of CO_2 emissions from limestone and dolomite use.

Table A.3.1.2.1. Amount of limestone and dolomite use in metallurgy

Use of limestone	Measure-ment units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Blast-furnace sinter production	kt	60926.5	51109.2	49473.2	40110.8	30376.8	26277.9	25817.8	29573.9	31539.0	35781.7	38801.3	41287.9
Specific standards for limestone use	kg/t	130.0	132.5	135.0	140.3	180.0	159.7	139.4	119.1	129.8	130.3	129.3	141.6
Specific standards for dolomite limestone use	kg/t	41.0	44.5	48.0	68.1	65.88	63.65	61.43	59.2	62.1	54.1	57.3	54.7
Limestone use	kt	7920.4	6772.0	6678.9	5627.5	5467.8	4196.6	3599.0	3522.3	4093.8	4662.4	5017.0	5846.4
Dolomite limestone use	kt	2498.0	2274.4	2374.7	2731.5	2001.2	1672.6	1586.0	1750.8	1958.6	1935.8	2223.3	2258.4
Iron ore pellets production	kt	27916.8	22144.1	19680.7	15248.3	12392.7	14584.8	12824.3	14959.5	12842.9	9619.2	12343.4	11951.9
Specific standards for limestone use	kg/t	49.03	49.03	49.03	49.03	49.03	49.03	49.03	49.03	49.03	49.03	49.03	49.03
Limestone use	kt	1368.8	1085.7	964.9	747.6	607.6	715.1	628.8	733.5	629.7	471.6	605.2	586.0
Iron production	kt	44927.4	36632.1	35350.0	27108.0	20180.3	17998.4	17831.5	20616.0	20936.7	23009.8	25698.7	26378.5
Specific standards for limestone use	kg/t	73	26	48	35	70	73.57	77	81	59	58	69	66
Specific standards for dolomite limestone use	kg/t	8	8	8	8	8	25	41	58	58	51	10	8
Limestone use	kt	3281.03	937.8	1703.9	948.8	1412.6	1324.1	1375.5	1663.7	1239.5	1336.9	1778.4	1746.3
Dolomite limestone use	kt	368.4	300.4	289.9	222.3	165.5	445.8	737.2	1193.7	1206.0	1171.2	249.3	216.3
Steel production	kt	52635.4	44994.5	41759.2	32609.7	24081.2	22307.9	22332.9	25628.5	24446.5	27392.2	31781	33522.1
Specific standards for limestone use	kg/t	24.6	24.6	24.6	24.6	21.3	20.94	20.58	20.23	24.28	24.71	24.95	25.19
Specific standards for dolomite limestone use	kg/t	9.8	9.8	9.8	9.8	8.6	8.57	8.54	8.51	4.9	5.3	5.68	6.05

Continuation of Table A3.1.2.1

Use of limestone	Measurement units	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Specific standards for dolomite use	kg/t	9.1	9.1	9.1	9.1	10.7	10.2	9.7	9.21	9.9	9.3	9.89	10.47
Limestone use	kt	1294.83	1106.86	1027.28	802.20	512.93	467.13	459.61	518.46	593.56	676.86	792.94	844.42
Dolomite limestone use	kt	515.83	440.95	409.24	319.58	207.10	191.18	190.72	218.10	118.81	143.81	180.52	202.81
Limestone and dolomite limestone use	kt	1810.66	1547.81	1436.52	1121.77	720.03	658.31	650.33	736.56	712.37	820.67	973.45	1047.23
Dolomite use	kt	478.98	409.45	380.01	296.75	257.67	227.54	216.63	236.04	240.80	253.65	314.31	350.98
Ferroalloys Production	kt	2135.5	1930.1	1026.5	1026.5	1026.5	1026.5	1026.5	1026.5	851.6	934.5	1279.7	1296.3
Specific standards for limestone use	kg/t	18.84	18.84	18.84	18.84	18.84	18.84	18.84	18.84	18.84	18.84	18.84	18.84
Limestone use	kt	40.2	36.4	19.3	19.3	19.3	19.3	19.3	19.3	16.0	17.6	24.1	24.4
Total limestone use	kt	13905.3	9938.7	10394.3	8145.5	8020.3	6722.3	6082.2	6457.2	6572.5	7165.3	8217.6	9047.5
Total dolomite limestone use	kt	3382.2	3015.7	3073.8	3273.4	2373.8	2309.6	2513.9	3162.5	3283.3	3250.8	2653.1	2677.6
Total use of limestone, including dolomite limestone	kt	17287.5	12954.4	13468.1	11418.9	10394.1	9031.9	8596.1	9619.8	9855.8	10416.1	10870.7	11725.0
Total use of dolomite	kt	479.0	409.4	380.0	296.7	257.7	227.5	216.6	236.0	240.8	253.7	314.3	351.0
Total limestone and dolomite use	kt	17766.5	13363.8	13848.1	11715.6	10651.8	9259.4	8812.7	9855.8	10096.6	10669.8	11185.0	12076.0
CO_2 emission factor at limestone use (incl. dolomite limestone)	g/t	0.4336	0.4337	0.4336	0.4338	0.4336	0.4337	0.4338	0.4338	0.4339	0.4338	0.4337	0.4336
CO_2 emission factor for dolomite use	kg/t	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645
CO_2 emissions from limestone use (incl. dolomite limestone)	kt	7495.5	5617.7	5840.4	4953.1	4507.4	3917.1	3728.8	4173.5	4276.0	4518.6	4714.4	5084.5
CO_2 emissions from dolomite use	kt	222.5	190.2	176.5	137.8	119.7	105.7	100.6	109.6	111.9	117.8	146.0	163.0
Total CO_2 emission from limestone and dolomite use	kt	7718.013	5807.9	6016.9	5090.9	4627.1	4022.8	3829.4	4283.1	4387.8	4636.5	4860.4	5247.5
Total CO_2 emission factor	kg/t	0.4344	0.4346	0.4345	0.4345	0.4344	0.4345	0.4345	0.4346	0.4346	0.4345	0.4345	0.4345

Continuation of Table A3.1.2.1

Use of limestone	Measure-ment units	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Blast-furnace sinter production	kt	42991.6	43883.3	48134.0	48582.8	49002.8	51216.8	44553.1	35863.3	39492.6	40219.6
Specific standards for limestone use	kg/t	139.6	132.95	126.3	155.3	125.2	156.0	148.4	152.7	131.7	132.8
Specific standards for dolomite limestone use	kg/t	41.8	53.2	64.6	42.2	54.6	30.8	24.0	23.6	23.2	31.5
Specific standards for dolomite use	kg/t	-	-	-	-	-	-	-	-	-	-
Limestone use	kt	6001.6	5834.3	6079.3	7544.9	6135.2	7989.8	6611.7	5476.3	5201.2	5341.2
Dolomite limestone use	kt	1797.0	2334.6	3109.5	2050.2	2675.6	1577.5	1069.3	846.4	916.2	1266.9
Dolomite use	kt	-	-	-	-	-	-	-	-	-	-
Iron ore pellets production	kt	13464.9	14968.4	16348.1	17062.9	18313	18835.2	20414.1	20435.0	22141.0	22354.8
Specific standards for limestone use	kg/t	49.0	49.03	49.03	49.03	49.03	49.03	59.26	49.03	38.8	34.7
Specific standards for dolomite limestone use	kg/t	-	-	-	-	-	-	-	-	-	-
Limestone use	kt	660.2	733.9	801.5	836.6	897.9	923.5	1209.7	1001.9	859.1	775.7
Dolomite limestone use	kt	-	-	-	-	-	-	-	-	-	-
Iron production	kt	27633.3	29529.0	30977.6	30746.1	32929.3	35649.7	30991.3	25683.1	27365.8	28877
Specific standards for limestone use	kg/t	59.9	55	49	50	33	48	31	30	31	37.9
Specific standards for dolomite limestone use	kg/t	4.0	4	4	12	18	10	7	3	0.1	0.1
Limestone use	kt	1655.2	1609.3	1521.0	1537.3	1073.5	1707.6	954.5	765.4	859.3	1094.4
Dolomite limestone use	kt	110.5	124.0	136.3	356.7	589.4	349.4	226.2	66.8	2.7	2.9
Steel production	kt	34546.4	37524.1	38718.5	38615.5	40891.8	42828.5	37082.3	29848.6	32682	34762
Specific standards for limestone use	kg/t	21.1	19.06	16.99	15.68	14.33	12.3	13.31	9.98	12.88	14.87
Specific standards for dolomite limestone use	kg/t	5.9	5.34	4.74	4.03	5.29	4.19	3.6	2.02	1.35	1.41
Specific standards for dolomite use	kg/t	11.02	10.88	10.73	10.77	8.26	8.79	7.48	6.33	4.04	4.12

Continuation of Table A3.1.2.1

Use of limestone	Measurement units	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Limestone use	kt	719.4	703.9	657.8	605.5	586.0	526.8	497.9	297.9	420.9	516.911
Dolomite limestone use	kt	202.3	197.2	183.5	155.6	216.3	179.5	134.7	60.3	44.1	49.014
Limestone and dolomite limestone use	kt	921.7	901.1	841.4	761.1	802.3	706.2	632.6	358.2	465.1	565.9
Dolomite use	kt	375.3	401.8	415.4	415.9	337.8	376.5	279.8	188.9	132.0	143.2
Ferroalloys Production	kt	1288.3	1490.0	1912.3	1632.4	1709.6	1867.9	1662.8	1200.7	1671.3	1419.6
Specific standards for limestone use	kg/t	18.8	18.84	18.84	18.84	18.84	19.79	20.74	11.51	23.3	52.44
Limestone use	kt	24.3	28.1	36.0	30.8	32.2	37.0	34.5	13.8	38.9	74.4
Total limestone use	kt	9070.9	8920.8	9095.7	10555.1	8724.7	11184.7	9304.0	7555.3	7379.4	7802.7
Total dolomite limestone use	kt	2112.8	2659.0	3429.3	2562.5	3481.3	2106.3	1429.0	973.4	963.1	1318.8
Total use of limestone, including dolomite limestone	kt	11183.7	11579.8	12525.0	13117.5	12206.0	13291.0	10733.0	8528.8	8342.5	9121.5
Total use of dolomite	kt	380.7	408.3	415.4	415.9	337.8	376.5	277.4	188.9	132.0	143.2
Total limestone and dolomite use	kt	11564.43	11988.1	12940.5	13533.4	12543.8	13667.4	11010.4	8717.7	8474.5	9264.7
CO_2 emission factor at limestone use (incl. dolomite limestone)	kg/t	0.4336	0.4336	0.4337	0.4336	0.4338	0.4335	0.4335	0.4334	0.4334	0.4335
CO_2 emission factor for dolomite use	kg/t	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645
CO_2 emissions from limestone use (incl. dolomite limestone)	kt	4848.9	5021.5	5432.5	5687.5	5294.5	5761.7	4652.3	3696.52	3615.81	3954.0
CO_2 emissions from dolomite use	kt	176.8	189.6	193.0	193.2	156.9	174.9	128.8	87.7661	61.3319	66.5
Total CO_2 emission from limestone and dolo-mite use	kt	5025.7	5211.2	5625.5	5880.7	5451.4	5936.6	4781.1	3784.28	3677.14	4020.5
Total CO_2 emission factor	kg/t	0.4346	0.4347	0.4347	0.4345	0.4346	0.4344	0.4342	0.4341	0.4339	0.4340

Continuation of Table A3.1.2.1

Use of limestone	Measure-ment units	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Blast-furnace sinter production	kt	42598.0	43624	38294.60	33575.72	34383	31000	31680	30911	31907	32917
Specific standards for limestone use	kg/t	119.42	122.296	118.111	101.079	112.532	123.209	111.79	128.22	122.322	123.501
Specific standards for dolomite limestone use	kg/t	33.195	33.994	26.517	48.065	59.791	22.407	73.223	66.423	48.99	50.162
Specific standards for dolomite use	kg/t	1.684	1.724	3.796	2.076	6.847	4.31	0.0	0.0	0.0	0.000
Limestone use	kt	5087.053	5335.1	4523.029	3393.809	3869.183	3819.490	3541.543	3963.451	3902.92	4065.289
Dolomite limestone use	kt	1414.041	1483	1015.478	1613.809	2055.791	694.631	1728.3	1571.88	1250.82	1651.197
Dolomite use	kt	71.735	75.2	145.4	69.707	235.417	133.622	0.0	0.0	0.0	0.0
Iron ore pellets production	kt	21959.6	23702	21915	21657	22386	20100	21360	20807.75	18886.42	20133.92
Specific standards for limestone use	kg/t	27.954	30.172	27.897	27.5688	28.497	25.587	27.27	27.272	27.272	27.272
Specific standards for dolomite limestone use	kg/t	2.65	2.86	2.64	2.613483	2.701	2.426	2.59	2.585	2.585	2.585
Limestone use	kt	613.858	715.1	611.4	597.1	637.9	514.3	582.5	567.46	515.06	549.08
Dolomite limestone use	kt	58.193	67.8	57.96	56.60	60.47	48.75	55.22	53.79	48.83	52.05
Iron production	kt	28486.6	29088.7	24800.9	21862.8	23559.5	20116.5	20531.2	20055.9	20238	21165
Specific standards for limestone use	kg/t	32.18	32.19	26.497	22.605	10.302	16.811	28.658	23.832	28.894	44.518
Specific standards for dolomite limestone use	kg/t	1.565	0.242	3.281	3.756	0.873	9.37	13.925	9.936	0.645	10.655
Limestone use	kt	916.699	936.2	657.151	494.206	242.705	338.18	588.374	477.981	584.765	942.218
Dolomite limestone use	kt	44.582	7.0	81.379	82.121	20.571	188.49	285.895	199.273	13.051	225.506
Steel production	kt	32497.85	32673.02	27144.07	22997.61	24196	21049.27	20994.48	20848	20616	21366
Specific standards for limestone use	kg/t	12.79	12.99	13.84	13.160	10.67	11.538	12.00	11.594	10.46	10.36
Specific standards for dolomite limestone use	kg/t	0.769	0.78	1.3	0.019	0.64	1.495	1.43	1.074	1.17	0.922
Specific standards for dolomite use	kg/t	2.014	2.05	1.65	0.089	0.63	0.689	0.25	1.367	1.18	0.936

Continuation of Table A3.1.2.1

Use of limestone	Measure-ment units	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Limestone use	kt	415.583	424.302	375.608	302.658	258.194	242.872	251.996	241.705	215.658	221.38
Dolomite limestone use	kt	24.991	25.515	35.200	0.448	15.568	31.459	30.096	22.40	24.10	19.70
Limestone and dolomite limestone use	kt	440.6	449.82	410.808	303.1063	273.762	274.331	282.092	264.105	239.758	241.08
Dolomite use	kt	65.5	66.82	44.701	2.039	15.139	14.50	5.200	28.50	24.40	20.00
Ferroalloys Production	kt	1279.084	1142.21	1362.473	1092.13	1218.323	1278.99	1244.79	1183.93	853.67	1017.801
Specific standards for limestone use	kg/t	64.636	60.48	55.18	55.410	14.275	22.41	21.59	18.60	30.56	13.88
Limestone use	kt	82.675	69.1	75.18	60.515	17.391	28.67	26.87	22.02	26.09	14.12
Total limestone use	kt	7115.9	7479.8	6242.3	4848.2	5025.4	4943.5	4991.3	5272.6	5244.5	5792.1
Total dolomite limestone use	kt	1541.8	1583.3	1190.0	1753.0	2152.4	963.3	2099.5	1847.4	1336.8	1948.5
Total use of limestone, including dolo-mite limestone	kt	8657.7	9063.1	7432.35	6601.22	7177.81	5906.8	7090.83	7119.97	6581.29	7740.55
Total use of dolomite	kt	137.2	142.1	190.1	71.7	250.6	148.1	5.2	28.5	24.4	20.0
Total limestone and dolomite use	kt	8794.9	9205.2	7622.5	6672.97	7428.36	6054.96	7096.03	7148.47	6605.69	7760.55
CO_2 emission factor at limestone use (incl. dolomite limestone)	kg/t	0.4335	0.4335	0.4335	0.4337	0.4338	0.4335	0.4338	0.4337	0.4336	0.4337
CO_2 emission factor for dolomite use	kg/t	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645
CO_2 emissions from limestone use (incl. dolomite limestone)	kt	3753.5	3929.2	3222.0	2863.1	3113.6	2560.7	3075.86	3087.98	2853.61	3357.01
CO_2 emissions from dolomite use	kt	63.7	66.0	88.3	33.3	116.4	68.8	2.4	13.2	11.3	9.3
Total CO_2 emission from limestone and dolomite use	kt	3817.2	3995.2	3310.3	2896.4	3230.0	2629.5	3078.3	3101.2	2864.9	3366.3
Total CO_2 emission factor	kg/t	0.4340	0.4340	0.4343	0.4341	0.4348	0.4343	0.4338	0.4338	0.4337	0.4338

A3.1.3 Method of CO_2 emission factor determination for coke use

The CO_2 emission factor for coke use *(kc)* is determined under the equation:

$$kc = (dc / 100) \cdot 44/12,$$

where *dc* is the carbon content in coke used in the blast furnace process for iron production, %.

The carbon content in coke is determined based on data obtained from enterprises-producers of pig iron. Results of estimations using described methods are the values of carbon content in coke of 86.3 % (for dry coke), and of CO_2 emission factor at coke use calculated on basis of national data in 2021 amounted to 3.17 tons of CO_2/t.

A3.1.4 Carbon balance in the blast furnace process

Tables A3.1.4.1- A3.1.4.2 show the income and expense side of the carbon balance in the blast furnace process in 2021.

Table A3.1.4.1. The income side of the carbon balance in the blast furnace process in 2021

Fuel and materials for pig iron production	**Data source**	**Amount of fuel and materials, kt (M m3)**	**Specific carbon content t of C/t (t of C/ M m3)**	**Carbon content at the input of the blast furnace process, kt**
Limestone	Table P3.1.3.1	942.218	0.118	111.316
Dolomite limestone	Table P3.1.3.1	225.506	0.119	26.764
Blast-furnace coke use	Table P3.1.1.15	10667.304	0.863	9210.436
Coal	Table P3.1.1.15	97.8187056	0.800	78.218
Natural gas	Table P3.1.1.15	1.5023036	0.525	0.788
The total amount of carbon	The total of all components			9427.523

Table A3.1.4.2 The expense side of the carbon balance in the blast furnace process in 2021

Components of carbon emissions	**Data source**	**Amount of fuel and materials, kt (M m3)**	**Specific carbon content t of C/t (t of C/M m3)**	**Carbon content at the output of the blast furnace process, kt**	**Category where the carbon emissions are accounted for**
Limestone use	Table P3.1.3.1	942.218	0.118	111.316	-
Dolomite limestone use	Table P3.1.3.1	225.506	0.119	26.764	-
Coke use	With using extrapolation method, based on data of the growth of pig iron production in 2021	10667.304	0.863	9210.436	2.C.1.1
Carbon residue in pig iron	Table P3.1.3.1	21165	0.045	954.611	2.C.1.1
Emissions from use of the technological component of coke	"Technological coke component" minus "Carbon residue in pig iron"			8255.826	2.C.1.1
Coal use	Table P3.1.3.1	97.8187056	0.800	78.218	2.C.1.1
Natural gas use	Table P3.1.3.1	1.5023036	0.525	0.788	2.C.1.1
The total amount of carbon	The total of all components			9427.523	
Carbon emissions from iron production	The total of all components accounted for in category 2.C.1.1			8472.912	2.C.1.1
CO_2 emissions from iron production	Table P3.1.3.1			31 067.34	2.C.1.1

A3.2 Agriculture (CRF sector 3)

A3.2.1 Livestock

A3.2.1.1 Harmonization with the forms of the State Statistics Service of Ukraine

The SSSU provides quite detailed information about number and fodder consumption of livestock and poultry. Statistical observations conducted according to approved methodological recommendations [4, 21]. The collection of statistical observations at the regional and state levels carried out according to the scheme, as shown in the Figure A3.2.1.1.1.

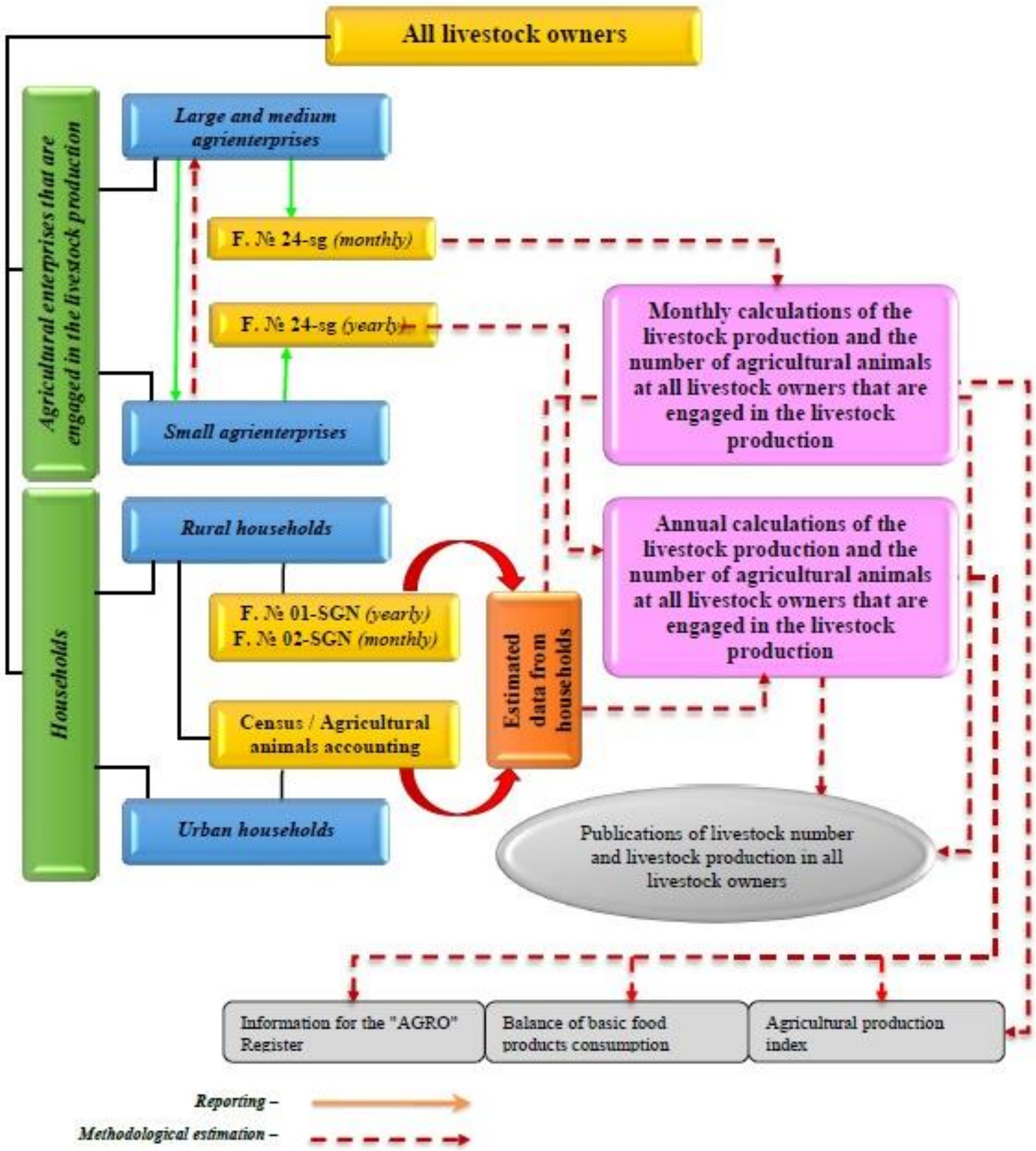

Figure A3.2.1.1.1. General scheme of statistical observations on the livestock production, the number of agricultural animals, their fodders provision and the interconnection with other statistical forms

However, groups of animals in the statistics do not fully coincide with the groups to be used for the inventory of GHG emissions, as the statistical information is designed for a wide range of users, i.e. not adapted for GHG inventory. For example, not all sex-age groups of animals singled out from the total population in SSSU data. Given the above, it is necessary to coordinate the groups of animals according SSSU and the groups that should be used for the inventory. The groups of animals for the purpose of the GHG inventory selected in accordance with the recommendations of the Good Practice Guidance based on the difference in the amount of feed consumed, the amount of manure excreted, and other data.

Table A3.2.1.1.1 presents the comparison of species and sex-age groups of cattle, swine, poultry, and sheep at farms according to the SSSU and the groups used in the NIR.

Table A3.2.1.1.1. The correspondence of animal species/groups at agrienterprises according to the SSSU and the species/groups used for the inventory

<table>
<tr><th colspan="2">SSSU species/groups of animals</th><th>The code of the species/group of animals in form No.24</th><th>Species/groups of animals for the GHG inventory</th><th>CRF categories</th></tr>
<tr><td colspan="5">Cattle</td></tr>
<tr><td rowspan="3">Cows (without cows on fattening) - 40 (2)</td><td>Dairy herd cows</td><td>40 (2) – 83-87</td><td rowspan="2">Dairy cows</td><td rowspan="2">Mature dairy cattle</td></tr>
<tr><td>Dairy herd cows separated for group suckling rearing of calves</td><td>83</td></tr>
<tr><td>Beef cows</td><td>87</td><td>Beef cows</td><td rowspan="5">Other mature cattle</td></tr>
<tr><td colspan="2">Heifers 2 years and older, bred</td><td>81</td><td rowspan="2">Heifers 2 years and older</td></tr>
<tr><td colspan="2">Heifers 2 years and older, not bred</td><td>82</td></tr>
<tr><td colspan="2">Beef and dairy cows on fattening*</td><td>-</td><td>Cows on fattening</td></tr>
<tr><td colspan="2">Bulls</td><td>84</td><td>Bulls</td></tr>
<tr><td colspan="2">Beef cattle (excluding cows)</td><td>86-87</td><td rowspan="2">Cattle on fattening (excluding cows)</td><td rowspan="6">Growing cattle</td></tr>
<tr><td colspan="2">Cattle on fattening (excluding cows)*</td><td>-</td></tr>
<tr><td colspan="2">Heifers from 1 to 2 years, bred</td><td>80</td><td>Heifers from 1 to 2 years</td></tr>
<tr><td colspan="2">Calves under 1 year</td><td>77</td><td rowspan="3">Other cattle</td></tr>
<tr><td colspan="2">Draught oxen</td><td>85</td></tr>
<tr><td colspan="2">Cattle not included into the groups above (remainder)</td><td>-</td></tr>
<tr><td colspan="5">Swine</td></tr>
<tr><td colspan="2">Main sows</td><td>89</td><td>Main sows</td><td rowspan="7">Swine</td></tr>
<tr><td colspan="2">Sows tested</td><td>90</td><td>Sows tested</td></tr>
<tr><td colspan="2">Repair swine older than 4 months</td><td>91</td><td>Repair swine older than 4 months</td></tr>
<tr><td colspan="2">Piglets up to 2 months</td><td>92</td><td>Piglets up to 2 months</td></tr>
<tr><td colspan="2">Fattening swine*</td><td>-</td><td>Fattening swine</td></tr>
<tr><td colspan="2">Not allocated as a separate group</td><td>-</td><td>Boars</td></tr>
<tr><td colspan="2">Not allocated as a separate group</td><td>-</td><td>Piglets 2 to 4 months</td></tr>
<tr><td colspan="5">Poultry</td></tr>
<tr><td colspan="2">Adult hens and roosters</td><td>110 (1)</td><td rowspan="2">Hens and roosters</td><td rowspan="10">Poultry</td></tr>
<tr><td colspan="2">Young hens and roosters</td><td>110 (2)</td></tr>
<tr><td colspan="2">Adult geese</td><td>112 (1)</td><td rowspan="2">Geese</td></tr>
<tr><td colspan="2">Young geese</td><td>112 (2)</td></tr>
<tr><td colspan="2">Adult ducks</td><td>113 (1)</td><td rowspan="2">Ducks</td></tr>
<tr><td colspan="2">Young ducks</td><td>113 (2)</td></tr>
<tr><td colspan="2">Adult turkeys</td><td>114 (1)</td><td rowspan="2">Turkeys</td></tr>
<tr><td colspan="2">Young turkeys</td><td>114 (2)</td></tr>
<tr><td colspan="2">Other adult poultry</td><td>115 (1)</td><td rowspan="2">Other poultry</td></tr>
<tr><td colspan="2">Other young poultry</td><td>115 (2)</td></tr>
<tr><td colspan="5">Sheep</td></tr>
</table>

SSSU species/groups of animals	The code of the species/group of animals in form No.24	Species/groups of animals for the GHG inventory	CRF categories
Ewes and gimmers 1 year and older	94	Ewes and gimmers 1 year and older	Sheep
Not allocated as a separate group	-	Rams	
Not allocated as a separate group	-	Wethers	
Fattening livestock *	-	Fattening livestock	
Sheep not included into the groups above (remainder)	-	Lambs up to 4 months and 4-12 months repair young sheep	

* Statistics on the livestock of fattening cattle, swine, and sheep are not maintained since 2005.

Similar to agrienterprises, statistical data on the sex-age of animals in households do not fully coincide with the groups to be used for inventory of GHG emissions.

Therefore, harmonization of groups of animals according to SSSU data and groups used for inventory purposes was held (Table A3.2.1.1.2).

Table A3.2.1.1.2. Matching groups of animals according to the SSSU and the groups used for inventory purposes

SSSU species/groups of animals	Code of the species/group of animals in Table No.7, field	Species/groups of animals for the GHG inventory	CRF categories
Cows (without cows on fattening)	3	Dairy cows	Mature dairy cattle
Heifers 2 years and older (bred and not bred)	5	Heifers 2 years and older	Other mature cattle
Bulls	2	Bulls	
Heifers from 1 to 2 years, bred	4	Heifers from 1 to 2 years	Growing cattle
Cattle not included into the groups above (remainder)	-	Other cattle	
Main sows	9	Main sows	Swine
Repair swine 4 months and older	11	Repair swine 4 months and older	
Piglets up to 2 months	12	Piglets up to 2 months	
Not allocated as a separate group	-	Piglets 2 to 4 months	
Not allocated as a separate group	-	Boars	
Not allocated as a separate group	-	Fattening swine	
Hens and roosters	-	Hens and roosters	Poultry*
Geese	-	Geese	
Ducks	-	Ducks	
Turkeys	-	Turkeys	
Other poultry	-	Other poultry	
Ewes and gimmers 1 year and older	14	Ewes and gimmers 1 year and older	Sheep
Not allocated as a separate group	-	Rams	
Not allocated as a separate group	-	Wethers	
Not allocated as a separate group	-	Lambs up to 4 months and 4-12 months young sheep	

* The SSSU determines the livestock of poultry by species by calculation according to state statistical observation form No.01-SHN "Basic interview questionnaire" (section II) on the basis of percentage ratio of the poultry species specified in Table A3.2.1.2 in the poultry flock structure.

A3.2.1.2 Sources of data on livestock

In line with the requirements of [1], developers of the GHG inventory report are supposed to use data of the SSSU or FAO as the information base to estimate the average annual livestock.

Determination of average livestock, according to information received from SSSU carried out by using the approach [35], which reflects the national characteristics and consists in calculating the arithmetic value of livestock at the beginning and end of the relevant year.

The agreement of national approach for calculating the annual average number of animals with the 2006 IPCC Guidelines [1] are planned by realization of research work on relevant topic.

A3.2.1.2.1 Data sources on cattle livestock

Sources of information about the cattle population as of January 1 by category of farms and cattle sex-age groups for the reporting period were cattle accounting data ("Livestock accounting results", Table No.7; "Statistical reported data: Number of agricultural animals as of January 01" [38]), bulletin or statistical reported data by the state statistical observation form No.24 (statistical bulletin "The status of livestock in Ukraine" [13] and "Statistical reported data: Production of animal products" [39]) and analytical study, which includes different approaches, particularly extrapolation, expert judgment and other math and statistical methods [2].

The average annual population of each sex-age group of cattle at agricultural enterprises and in households was determined in accordance to national methodology [35]. Results of estimation of the average annual cattle livestock at agrienterprises and in households in the areas of Polissia, Wooded Steppe, and Steppe reported in Annex 3 (Tables A3.2.1.3.1 and A3.2.1.3.2).

A3.2.1.2.2 Data sources on sheep livestock

According to recommendations [1] and by using national sources [9], the livestock was divided by sex-age groups: ewes and gimmers 1 year and older, rams, fattening livestock, wethers, lambs up to 4 months and 4-12 months repair young sheep.

Data on the livestock of sheep of all breeds in all categories of farms were obtained from SSSU data ("Livestock accounting results", Table No.7; "Statistical reported data: Number of agricultural animals as of January 01" [38]) and analytical study [2]. These sources specifies the total livestock of sheep, while the livestock of ewes and gimmers 1 year old and older indicated as a separate group. The average annual population sheep for all categories of farms was determined in accordance to national methodology [35]. The livestock of rams and wethers calculated on the base of information on the sheep herd structure obtained from the SSSU (for 1990) and the Agency for Identification and Registration of Animals. Fattening livestock includes young animals (mostly 7 to 9 months old), adult culled ewes and rams. The calculations according to [6-7] assumed that the proportion of young sheep in fattening livestock is 83.5 %, while of adult – 16.5 %. The rest of sheep population ascribed to lambs under 4 months and repair young animals up to 1 year.

Sheep livestock distribution in the territory of Ukraine is not homogeneous. Mostly, sheep are bred in such key sheep-breeding regions as the Autonomous Republic of Crimea, Transcarpathian, Zaporizhska, Odeska, Dnipropetrovska, Donetska, Khersonska, Mykolaivska, and several other regions, most of which are located in the steppe zone. In determining the above-mentioned regions, data on placement of breeds and breed sheep types in the regions of Ukraine according to [7], as well as statistical data on the population of sheep in all kinds of farms by region takes into account [10].

A3.2.1.2.3 Data sources on swine livestock

Data on the livestock of key sex-age groups of swine at farms and in households were obtained from SSSU data ("Livestock accounting results", Table No.7; "Statistical reported data: Number of agricultural animals as of January 01" [38]) and analytical study [2].

In accordance to statistical bulletin swine livestock at agricultural enterprises was divided into five sex-age groups up to 2005, and later on 2005 – into 4 groups. The animals that do not belong to these groups on average during the reporting period amount to one third of the total swine population. In particular, in the statistics there is no separate indications of the livestock of boars and piglets from 2 to 4 months. Boars usually account for about 1% of the total population, and their number for the reporting period was estimated on the basis of this assumption. The repair swine were attributed to piglets from 2 to 4 months. Data on the population of swine for fattening from 2014, due to lack of statistical data, were estimated based on the percentage of this group in the herd structure in 2004 (29.5 %). Statistics on the livestock of piglets up to 2 months introduced in 2001. The number of piglets for 1990-2000 was estimated based on the structure of the swine herd in 2001-2004.

The livestock of swine in households in accordance with statistics is divided into the three age and sex groups: main sows, repair swine 4 months of age and older, and piglets up to 2 months [35]. The following groups are not indicate separately: boars, piglets from 2 to 4 months, and swine for fattening. The number of boars and piglets from 2 to 4 months in households was assumed to be 1 and 22 % of the total population, respectively. The number of fattening swine calculated as the difference between the total population and all the age and sex groups used for the inventory. Statistics on the livestock of piglets up to 2 months introduced in 2000. The number of piglets for the rest of the years was estimated based on the structure of the swine herd in 2000-2004.

The average annual population of sex-age groups of swine from "Livestock accounting results" (Table No.7) and analytical study [2] at agricultural enterprises and in households was determined in accordance to national methodology [35].

A3.2.1.2.4 Data sources on poultry livestock

The values of the poultry livestock are presented in statistical bulletin "The status of livestock in Ukraine", statistical yearbook "Animal production of Ukraine", statistical reported data "Number of agricultural animals as of January 01" and "Production of animal products" [10, 13, 38-39] by species hens and roosters, geese, ducks, and turkeys) and age group (adults and young ones). The analytical study [2] used for poultry livestock calculation also. The breakdown of poultry by sex-age groups for GHG inventory not applied due to lack of all the necessary data.

Total poultry population (without the breakdown into species) is determined on the base of the sample data of the household survey in rural communities. First, the population of poultry per household estimated, and then these data are spread to the number of households that keep poultry in accordance with the census of animals as of January 1. The poultry population by species (hens and roosters, geese, ducks, and turkeys) estimation based on the poultry structure at households [10].

The average annual population of sex-age groups of poultry at agricultural enterprises and in households was determined in accordance to national methodology [35].

A3.2.1.2.5 Data sources on livestock of other animals

Other animals (horses, goats, asses and mules, rabbits, fur-bearing animals, camels, and buffaloes) determined according to SSSU data ("Livestock accounting results", Table No.7; statistical reported data "Number of agricultural animals as of January 01" [38]; statistical reported data "Production of animal products" [39]; statistical bulletin "The status of livestock in Ukraine" [13], statistical yearbook "Animal Production of Ukraine" [10], FAO data, analytical study [2] or based on assumptions. The average annual population of the groups of animals indicated (except for camels, asses and mules was determined in accordance to national methodology [35].

Breeding of buffaloes, camels, asses and mules as agricultural animals is not widely practiced in Ukraine, their livestock are not included into indicators of state statistical observations on livestock statistics or the state registry, which is being composed by State Enterprise "Agency of Animal Identification and Registration". Despite the negligible livestock, buffaloes, camels, asses and mules are included into the estimation of the GHG inventory to ensure data completeness. Within Ukraine, buffaloes are bred mainly in the Transcarpathian region. Official data on the number of these animals are limited to 1990 and 2010-2015. The number of buffaloes in the period of 1991-2009 was calculated using linear interpolation method. According to data of the Department of Agricultural Development of Transcarpathian Regional State Administration, the average annual number of buffaloes in 2015 decreased compared to 1990 by 6.8 % and went down to 58 animals.

Data on the average annual population of camels, asses and mules are not included into the set of indicators of state statistical observations forms of livestock statistics. The source of information is the FAO information database (http://faostat.fao.org).

Moreover, the SSSU also provides no information on the population of fur-bearing animals for the periods of 1990-1993 and 1995-1997. It has assumed that the number of fur-bearing animals for 1990 is the same as the population in 1989. The numbers of these animals for 1991-1993, as well as for 1995-1997 obtained using the linear interpolation method.

A3.2.1.3 The average annual livestock of animals

Table A3.2.1.3.1. The average annual livestock at agricultural enterprises and households, thsd. head

Animal species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agrienterprises	21 373.90	20 636.85	19 502.10	18 276.20	16 753.70	14 735.10	12 636.00	10 282.65	8 438.50	7 293.95
Cattle at households	3 535.20	3 538.65	3 590.10	3 755.85	3 862.10	3 855.70	3 799.25	3 753.20	3 801.55	3 880.10
Sheep	8 220.80	7 577.65	6 927.80	6 357.20	5 455.10	4 000.80	2 701.25	1 866.40	1 369.00	1 128.95
Swine at agrienterprises	14 530.10	13 317.20	11 746.45	10 339.35	8 915.40	7 617.15	6 344.70	4 779.90	4 153.35	4 198.30
Swine at households	5 156.70	5 315.60	5 260.35	5 397.10	5 706.35	5 927.80	5 845.30	5 577.25	5 627.70	5 879.85
Fur-bearing animals	560.95	560.95	561.00	560.50	544.00	496.00	432.00	368.00	319.70	268.15
Rabbits	6 097.50	6 252.05	6 495.30	6 842.65	6 828.55	6 566.85	6 106.20	5 634.25	5 548.35	5 636.85
Camels	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Asses and mules	19.00	19.00	19.00	19.00	15.00	14.50	14.00	13.00	12.50	12.00
Buffaloes	0.85	0.83	0.79	0.75	0.71	0.67	0.63	0.59	0.55	0.51
Horses	745.95	727.75	712.10	711.40	726.15	746.25	754.70	745.20	729.10	709.70
Goats	490.10	546.25	605.05	692.40	763.45	835.75	871.60	838.05	824.90	826.40
Poultry at agrienterprises	137 593.50	130 465.75	116 352.15	94 631.40	74 695.20	59 470.60	44 207.00	32 328.25	30 709.90	29 483.60
Poultry at households	113 018.35	114 146.65	112 499.30	107 900.00	102 976.80	97 835.35	95 391.85	94 066.40	95 697.10	98 304.85

Animal species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agrienterprises	5 871.45	4 850.30	4 428.55	3 679.40	2 927.80	2 591.20	2 393.20	2 110.70	1 823.45	1 673.60
Cattle at households	4 153.65	4 572.10	4 836.20	4 730.85	4 379.70	4 117.30	3 951.55	3 722.45	3 461.50	3 279.25
Sheep	1 011.30	965.10	958.60	921.75	884.30	873.70	898.44	979.22	1 064.73	1 146.35
Swine at agrienterprises	3 263.60	2 660.45	3 148.65	2 831.75	2 185.60	2 350.45	2 929.91	3 063.47	2 800.21	3 019.40
Swine at households	5 599.00	5 350.45	5 637.95	5 430.85	4 708.20	4 409.00	4 624.00	4 474.00	3 972.75	4 031.90
Fur-bearing animals	190.20	156.70	176.40	204.80	242.05	275.54	300.00	340.75	346.34	317.50
Rabbits	5 578.70	5 734.80	6 047.20	5 774.45	5 293.15	5 327.70	5 317.45	5 167.50	5 261.35	5 503.55
Camels	0.60	0.60	0.60	0.60	0.60	0.75	0.80	0.80	0.80	0.80
Asses and mules	11.50	11.50	11.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Buffaloes	0.47	0.43	0.40	0.36	0.32	0.28	0.24	0.20	0.16	0.12
Horses	699.65	697.30	688.85	660.70	614.00	572.85	544.57	515.92	481.65	454.60
Goats	868.55	954.90	1 016.10	999.85	929.85	825.80	724.91	668.66	638.01	633.35
Poultry at agrienterprises	26 608.50	30 258.05	38 434.00	41 983.80	46 410.05	58 591.30	69 422.15	76 171.65	84 049.00	94 163.85
Poultry at households	98 303.95	100 008.45	103 694.20	102 925.80	101 168.45	98 797.05	94 840.10	91 739.00	89 374.10	90 337.20

Animal species	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle at agrienterprises	1 576.75	1 518.50	1 508.55	1 472.00	1 387.12	1 320.55	1 277.35	1 227.97	1 192.14	1 133.44
Cattle at households	3 083.80	2 941.60	3 027.30	3 117.95	2 907.87	2 677.39	2 632.33	2 576.51	2 438.09	2 277.04
Sheep	1 148.75	1 096.85	1 083.30	1 070.05	1 030.47	972.72	938.53	930.75	921.50	887.14
Swine at agrienterprises	3 466.55	3 472.20	3 438.05	3 717.90	3 873.48	3 860.36	3 781.91	3 580.76	3 496.94	3 495.13
Swine at households	4 301.95	4 194.60	4 036.90	4 031.55	3 878.73	3 595.39	3 340.94	3 058.45	2 824.41	2 634.72
Fur-bearing animals	304.60	366.20	420.35	379.35	334.75	297.65	273.92	338.13	420.31	431.11
Rabbits	5 487.65	5 498.70	5 650.10	5 696.45	5 603.49	5 429.63	5 355.37	5 237.89	5 113.71	4 988.26
Camels	0.80	0.80	0.80	0.80	0.80	0.81	0.83	0.84	0.84	0.84
Asses and mules	12.00	12.00	12.00	12.00	12.00	11.94	11.86	11.85	11.96	11.97
Buffaloes	0.08	0.06	0.06	0.06	0.06	0.06	0.08	0.11	0.12	0.11
Horses	428.80	404.95	386.15	365.40	337.69	315.81	303.30	282.87	259.18	238.94
Goats	633.35	638.70	655.50	666.65	648.47	628.72	636.85	635.75	620.99	603.53
Poultry at agrienterprises	105 457.65	108 143.30	111 806.95	124 980.55	131 406.80	125 752.61	119 544.96	119 474.48	123 830.16	131 544.91
Poultry at households	92 185.35	94 156.90	95 608.65	97 199.65	96 725.95	95 369.44	95 347.49	95 472.48	95 993.10	96 167.48

Animal species	2020	2021
Cattle at agrienterprises	1 067.63	1 044.58
Cattle at households	2 113.34	1 921.79
Sheep	847.99	822.14
Swine at agrienterprises	3 611.44	3 749.74
Swine at households	2 441.96	2 245.91
Fur-bearing animals	382.06	374.56
Rabbits	4 892.73	4 816.58
Camels	0.85	0.85
Asses and mules	11.97	11.96
Buffaloes	0.10	0.10
Horses	217.90	196.10
Goats	578.73	549.48
Poultry at agrienterprises	127 034.57	119 887.42
Poultry at households	95 204.20	93 230.00

Table A3.2.1.3.2. The average annual number of cattle species in farms of different forms of ownership by the natural zones of Ukraine, thsd. head

Ecological region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mature dairy cattle at agrienterprises										
Polissia	1 264.20	1 220.00	1 146.60	1 078.80	1 027.20	972.95	907.30	801.45	690.45	591.90
Wooded Steppe	2 428.90	2 361.70	2 252.50	2 157.15	2 058.35	1 911.55	1 742.95	1 518.05	1 304.25	1 149.60
Steppe	2 579.95	2 507.85	2 408.95	2 303.45	2 149.25	1 922.75	1 674.90	1 379.95	1 129.65	949.10
Mature dairy cattle at households										
Polissia	953.95	963.15	993.30	1 036.00	1 085.80	1 131.45	1 151.55	1 159.70	1 172.80	1 181.05
Wooded Steppe	828.35	839.90	876.80	934.70	994.80	1 040.55	1 048.55	1 032.25	1 025.35	1 023.20
Steppe	397.55	427.80	481.75	557.35	632.60	695.55	726.35	726.95	730.30	741.05
Other mature cattle at agrienterprises										
Polissia	379.90	371.38	355.52	337.66	323.95	298.27	260.21	216.62	182.49	158.76
Wooded Steppe	943.58	922.28	885.42	846.56	816.51	745.76	641.45	529.15	442.74	384.73
Steppe	571.28	555.73	530.95	505.00	479.53	428.28	359.57	289.36	237.93	204.19
Other mature cattle at households										
Polissia	24.03	27.34	31.95	35.31	35.30	32.75	30.78	30.40	32.93	35.38
Wooded Steppe	22.56	25.67	29.99	33.16	33.15	30.77	28.92	28.56	30.93	33.23
Steppe	28.51	32.44	37.90	41.88	41.86	38.83	36.50	36.05	39.04	41.94
Growing cattle at agrienterprises										
Polissia	3 285.55	3 185.12	2 998.38	2 738.49	2 386.40	2 033.58	1 755.14	1 422.88	1 141.96	954.54
Wooded Steppe	4 916.92	4 751.12	4 506.14	4 238.14	3 886.75	3 401.79	2 935.95	2 402.25	1 961.91	1 727.22
Steppe	5 003.62	4 761.67	4 417.65	4 070.95	3 625.77	3 020.17	2 358.53	1 722.94	1 347.13	1 173.91
Growing cattle at households										
Polissia	493.37	463.66	416.60	383.69	341.45	297.30	277.12	277.60	288.02	311.07
Wooded Steppe	489.34	454.08	421.06	416.29	386.95	327.08	279.43	257.35	263.12	277.47
Steppe	297.54	304.61	300.75	317.47	310.20	261.42	220.05	204.36	219.06	235.71

Ecological region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mature dairy cattle at agrienterprises										
Polissia	482.85	407.45	358.85	296.65	254.25	235.80	216.60	195.30	178.05	165.30
Wooded Steppe	981.75	853.55	752.65	621.70	517.45	457.55	408.90	360.85	329.25	315.00
Steppe	699.00	502.10	427.00	332.55	253.25	214.70	189.60	165.15	144.15	134.15
Mature dairy cattle at households										

Ecological region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Polissia	1 194.30	1 221.25	1 240.55	1 209.75	1 138.30	1 063.20	992.35	923.50	854.75	804.25
Wooded Steppe	1 044.60	1 090.75	1 118.95	1 100.75	1 060.20	1 018.65	962.30	904.00	839.20	777.25
Steppe	792.15	863.10	918.85	938.15	881.30	790.65	721.15	672.50	630.70	600.45
Other mature cattle at agrienterprises										
Polissia	133.13	116.77	108.37	95.04	85.86	84.33	81.45	76.14	70.01	65.61
Wooded Steppe	321.56	281.04	260.37	224.72	188.58	163.10	141.74	123.29	106.49	97.44
Steppe	164.90	138.36	126.82	108.22	87.18	75.55	67.19	54.56	45.04	41.52
Other mature cattle at households										
Polissia	35.20	34.98	36.99	35.39	31.55	30.60	31.92	32.75	31.65	29.85
Wooded Steppe	33.08	32.89	34.81	33.31	29.71	28.89	29.94	29.67	28.52	27.10
Steppe	41.72	41.43	43.80	41.89	37.34	35.87	35.81	32.20	27.50	27.35
Growing cattle at agrienterprises										
Polissia	751.27	620.63	560.13	460.91	365.15	331.67	316.95	278.01	229.74	202.09
Wooded Steppe	1 440.14	1 252.01	1 192.73	1 011.68	797.77	701.50	653.46	579.16	497.71	457.21
Steppe	896.85	678.39	641.63	527.93	378.33	327.00	317.31	278.24	223.01	195.28
Growing cattle at households										
Polissia	349.00	396.42	437.01	410.46	343.35	317.85	336.43	339.75	324.80	311.20
Wooded Steppe	334.32	425.56	473.14	430.84	364.29	372.01	414.01	406.63	388.43	380.40
Steppe	329.28	465.72	532.10	530.31	493.66	459.58	427.64	381.45	335.95	321.40

Ecological region	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Mature dairy cattle at agrienterprises										
Polissia	157.30	152.90	150.90	149.10	139.75	127.25	119.85	115.40	114.65	111.75
Wooded Steppe	310.20	309.80	311.30	310.95	308.50	303.60	296.10	285.60	280.15	272.85
Steppe	129.35	123.70	117.25	110.25	103.31	96.72	91.88	88.71	87.22	83.33
Mature dairy cattle at households										
Polissia	770.05	745.25	734.55	724.10	688.55	644.10	618.80	592.40	557.65	519.70
Wooded Steppe	738.45	710.00	693.15	680.50	649.40	618.60	606.50	588.15	558.40	528.30
Steppe	578.50	565.05	561.10	556.65	538.10	513.06	499.69	490.03	468.63	436.19
Other mature cattle at agrienterprises										
Polissia	60.80	57.65	58.43	58.26	52.86	45.00	40.40	37.43	34.73	32.31
Wooded Steppe	89.11	83.58	82.92	82.14	79.31	74.23	67.58	61.52	58.87	54.59
Steppe	38.73	36.15	34.97	32.25	28.06	26.23	24.61	23.01	22.35	20.65

Ecological region	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Other mature cattle at households										
Polissia	28.10	26.45	24.20	22.60	21.75	20.80	20.00	18.95	17.90	16.85
Wooded Steppe	24.55	22.55	20.85	20.20	19.05	17.45	17.40	17.00	16.25	15.25
Steppe	28.15	28.65	29.30	30.30	30.06	28.80	27.51	26.50	25.13	22.53
Growing cattle at agrienterprises										
Polissia	182.05	169.21	169.57	163.04	145.34	137.55	134.55	128.43	122.07	113.74
Wooded Steppe	433.45	422.88	429.38	421.17	397.54	388.57	385.32	374.03	362.08	341.82
Steppe	175.77	162.65	153.83	144.85	132.46	121.40	117.07	113.85	110.03	102.41
Growing cattle at households										
Polissia	275.35	245.25	273.15	304.60	265.75	220.80	221.21	225.81	219.70	212.80
Wooded Steppe	337.85	308.65	361.90	404.05	343.05	299.05	310.35	305.95	283.95	265.70
Steppe	302.80	289.75	329.10	374.95	352.17	314.73	310.86	311.72	290.48	259.71

Ecological region	2020	2021
Mature dairy cattle at agrienterprises		
Polissia	104.40	101.05
Wooded Steppe	263.60	262.95
Steppe	77.67	74.67
Mature dairy cattle at households		
Polissia	482.15	447.00
Wooded Steppe	495.20	454.80
Steppe	405.29	371.24
Other mature cattle at agrienterprises		
Polissia	29.26	26.51
Wooded Steppe	49.45	47.24
Steppe	19.13	19.48
Other mature cattle at households		
Polissia	18.15	16.40
Wooded Steppe	13.65	12.85
Steppe	20.62	17.62
Growing cattle at agrienterprises		
Polissia	106.64	103.09
Wooded Steppe	323.20	320.46

Ecological region	2020	2021
Steppe	94.28	89.13
Growing cattle at households		
Polissia	199.20	183.65
Wooded Steppe	242.35	205.15
Steppe	236.74	213.09

A3.2.1.4 Classification of agricultural enterprises by the livestock number

The main institution that collected all kinds of livestock data is SSSU. Grouping of agricultural enterprises by the animals (cattle and swine) number is a one of data kinds.

These data used for agrienterprises classification by their capacity and reported in the next SSSU sources:

– for 1990-2017 – in the table "Groupings of agricultural enterprises by number of cattle as of January 01" of the statistical bulletin "The status of livestock in Ukraine" [13];

– since 2018 – in the SSSU statistical reported data "Groupings of enterprises by number of agricultural animals as of January 01" [37].

Table A3.2.1.4.1. Classification of cattle and swine enterprises by the livestock number, heads

Cattle enterprises		**Swine enterprises**	
SSSU sources in 1990-2017	*SSSU sources after 2018*	*SSSU sources in 1990-2017*	*SSSU sources after 2018*
no more than 5	no more than 50	no more than 9	no more than 100
6-10	50-99	10-19	100-199
11-15	100-499	20-39	200-499
16-20	500-999	40-59	500-999
21-29	1000-1499	60-79	1000-4999
30-39	more than 1500	80-99	5000-9999
40-49		100-199	more than 10000
50-99		200-299	
100-199		300-399	
200-299		400-499	
300-399		500-999	
400-499		1000-1999	
500-999		2000-2999	
1000-1999		3000-4999	
2000-2999		5000-5999	
3000-3999		more than 5999	
4000-4999			
more than 4999			

A3.2.2 Enteric Fermentation

Table A3.2.2.1. Annual gross energy intake of cattle sex-age groups, MJ × head $^{-1}$ × day $^{-1}$

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agrienterprises										
Cows	202.53	197.74	188.28	186.47	185.64	183.00	179.11	171.94	177.48	179.08
Heifers from 2 years and older	149.56	150.78	151.96	152.00	152.82	153.09	153.35	153.08	153.04	152.99
Heifers from 1 to 2 years	123.11	123.49	124.30	124.18	124.48	124.72	124.94	124.84	124.80	124.76
Breeding bulls	162.74	163.64	165.19	164.79	165.27	165.80	166.31	166.13	166.13	166.05
Beef cows	115.22	116.87	117.91	118.08	118.94	119.07	119.18	118.57	118.61	118.64
Cows on fattening and feeding	215.80	218.37	220.73	221.00	222.87	223.16	223.33	222.19	222.07	222.03
Other cattle and beef cattle (without cows) on fattening and feeding	101.00	102.19	103.22	103.36	104.22	104.37	104.46	104.00	103.94	103.93
Other cattle	89.33	89.55	90.21	90.15	90.35	90.51	90.66	90.50	90.46	90.42
Households										
Cows	211.92	211.66	210.91	211.59	211.33	212.46	212.36	213.73	214.99	215.54
Heifers 2 years and older	149.25	148.89	149.03	148.75	148.62	148.82	149.02	149.47	149.34	149.22
Heifers from 1 to 2 years	129.18	128.78	129.02	128.76	128.62	128.73	128.83	129.31	128.92	128.53
Breeding bulls	162.67	162.52	162.60	162.55	162.47	162.54	162.61	162.50	162.29	162.09
Other cattle	103.65	103.34	103.53	103.33	103.25	103.36	103.45	103.83	103.48	103.14

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agrienterprises										
Cows	176.32	187.05	189.77	186.21	195.90	206.29	209.04	210.12	214.76	227.26
Heifers from 2 years and older	152.96	152.93	152.87	152.83	152.78	152.71	152.15	152.30	151.31	152.20
Heifers from 1 to 2 years	124.71	124.67	124.63	124.58	124.52	124.47	124.01	124.12	123.36	123.93
Breeding bulls	165.96	165.86	165.78	165.69	165.59	165.28	165.01	165.31	164.41	165.23
Beef cows	118.68	118.72	118.76	118.74	118.64	118.48	118.04	118.24	117.13	117.69
Cows on fattening and feeding	221.84	221.58	221.55	221.47	221.27	221.16	220.34	220.70	219.00	220.72
Other cattle and beef cattle (without cows) on fattening and feeding	103.87	103.78	103.77	103.74	103.65	103.56	103.16	103.33	102.55	103.25
Other cattle	90.37	90.31	90.27	90.23	90.16	90.09	89.76	89.83	89.25	89.66
Households										
Cows	217.52	219.68	222.12	222.18	226.25	230.96	234.86	234.60	236.79	240.78
Heifers 2 years and older	149.06	148.90	148.76	148.61	148.45	148.33	148.34	148.46	148.55	148.20

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Heifers from 1 to 2 years	128.15	127.79	127.40	127.01	126.62	126.24	126.21	126.28	126.34	126.04
Breeding bulls	161.89	161.70	161.50	161.29	161.09	160.90	160.97	160.94	160.96	160.91
Other cattle	102.80	102.47	102.14	101.80	101.47	101.15	101.12	101.19	101.23	100.99

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agrienterprises										
Cows	229.11	225.57	238.14	242.34	250.11	257.16	264.55	271.78	274.24	276.52
Heifers from 2 years and older	152.05	151.81	151.74	151.84	153.08	153.30	153.49	153.89	157.67	157.01
Heifers from 1 to 2 years	123.77	123.58	123.50	123.52	124.25	124.33	124.10	124.42	127.06	126.72
Breeding bulls	165.16	164.85	165.42	165.89	166.76	166.86	167.28	166.75	169.14	168.81
Beef cows	117.95	117.31	117.05	117.65	119.14	119.65	122.01	122.16	127.19	126.73
Cows on fattening and feeding	220.52	220.02	219.97	220.19	222.57	222.95	223.62	224.42	231.78	230.41
Other cattle and beef cattle (without cows) on fattening and feeding	103.23	103.01	102.92	103.10	104.26	104.49	105.01	105.35	108.42	107.83
Other cattle	89.58	89.43	89.35	89.37	89.86	89.91	89.67	89.92	91.83	91.46
Households										
Cows	241.21	243.93	245.24	247.30	249.02	250.23	249.97	251.31	253.96	255.82
Heifers 2 years and older	148.14	147.96	147.94	148.04	147.92	147.92	147.95	147.97	147.75	147.76
Heifers from 1 to 2 years	126.01	125.87	125.86	125.96	125.87	125.89	125.91	125.92	125.72	125.71
Breeding bulls	160.91	160.88	160.89	160.92	160.93	160.95	160.96	160.95	160.91	160.92
Other cattle	100.96	100.85	100.84	100.92	100.85	100.86	100.87	100.89	100.73	100.72

Sex-age group	2020	2021
Agrienterprises		
Cows	285.43	288.42
Heifers from 2 years and older	158.20	158.09
Heifers from 1 to 2 years	127.40	127.43
Breeding bulls	169.64	169.50
Beef cows	128.22	127.92
Cows on fattening and feeding	232.93	232.30
Other cattle and beef cattle (without cows) on fattening and feeding	109.00	108.77
Other cattle	91.94	92.04
Households		

Sex-age group	2020	2021
Cows	256.94	260.25
Heifers 2 years and older	147.73	147.69
Heifers from 1 to 2 years	125.68	125.63
Breeding bulls	160.91	160.92
Other cattle	100.70	100.67

Table A3.2.2.2. Live weight weighted average values of main sex-age cattle groups for the reported period, kg

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mature dairy cattle	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73
Other mature cattle	479.12	478.99	478.88	478.85	478.85	479.51	480.35	480.95	481.73	482.50
Growing cattle	238.71	239.32	239.93	240.42	241.32	242.18	242.63	243.64	245.54	247.27

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Mature dairy cattle	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73
Other mature cattle	483.90	485.88	487.88	489.88	492.11	496.49	501.18	502.41	502.54	502.95
Growing cattle	250.08	253.27	254.83	255.86	257.01	259.12	261.93	263.52	264.81	266.16

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Mature dairy cattle	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73	576.73
Other mature cattle	502.10	500.88	501.76	501.24	498.30	496.75	497.26	497.86	497.30	497.38
Growing cattle	266.98	267.19	267.87	268.41	268.77	268.67	272.87	278.07	278.53	278.20

Sex-age group	2020	2021
Mature dairy cattle	576.73	576.73
Other mature cattle	497.56	497.95
Growing cattle	278.48	278.88

Table A3.2.2.3. The species composition of dairy and combined cattle breeds in Ukraine, as well as the average live weight of cattle sex-age groups

Breed	The species composition, %	Average live weight, kg					
		Dairy cows	Bulls	Heifers from 1 to 2 years	Heifers 2 years and older	Other cattle at agri-cultural enterprises	Other cattle in households
Ayrshire	0.02	460	840	350	410	203	226
Angler	0.41	450	830	355	420	203	228
White Head Ukrainian	0.01	470	850	325	400	193	221
Carpathian Brown	0.01	480	850	345	400	195	222
Ukrainian Dairy Brown	0.30	580	920	385	470	233	246
Holstein	10.94	565	900	420	470	238	264
Lebedynska	0.69	550	900	375	450	225	248
Pinzgauer	0.05	470	840	360	400	193	218
Simmental	5.97	620	960	400	465	243	279
Ukrainian Dairy Red	9.54	550	860	365	445	220	245
Ukrainian Dairy Red Motley	20.45	600	930	400	470	240	268
Ukrainian Dairy Black Motley	46.79	580	900	370	465	223	248
Red Polish	0.40	460	785	330	400	180	208
Red Steppe	4.36	490	830	360	420	208	221
Schwyz	0.04	580	950	380	450	230	248

Table A3.2.2.4. The cattle species composition and the average live weight of beef cattle in Ukraine

Breed	The species composition, %	Average live weight, kg	
		Beef cows	Breeding bulls
Aberdeen-Angus	35.93	515	800
Volyn Meat	21.25	520	900
Hereford	0.62	550	900
South Meat	11.36	530	880
Limousin	0.62	550	900
Piedmont	0.43	560	900
Woodland Meat	6.10	550	900
Grey Ukrainian	2.68	530	850
Fair Aquitaine	0.19	550	900
Simmental Meat	8.87	600	950
Ukrainian Meat	10.72	570	950
Charolais	1.24	600	950

Table A3.2.2.5. Country specific daily weight gain values for the cattle sex-age groups, kg × day $^{-1}$

Sex-age group	Agrienterprises	Households
Cows	0	0
Heifers from 2 years and older	0.525	0.525
Heifers from 1 to 2 years	0.475	0.475
Breeding bulls	0	0
Beef cows	0	
Cows on fattening and feeding	0.900	
Other cattle and beef cattle (without cows) on fattening and feeding	0.660	
Other cattle	0.725	0.725

Table A3.2.2.6. Dairy cows milk production and fat content

Type of livestock ownership	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Milk production, kg × head^{-1} × day^{-1}										
Cows at agrienterprises	8.06	7.31	5.96	5.75	5.56	5.23	4.67	3.81	4.51	4.71
Cows at households	7.22	7.25	7.22	7.32	7.30	7.46	7.40	7.62	7.76	7.86
Fat content of milk, %										
Cows at agrienterprises	3.48	3.45	3.37	3.38	3.37	3.35	3.38	3.36	3.41	3.43
Cows at households	3.48	3.45	3.37	3.38	3.37	3.35	3.38	3.36	3.41	3.43

Type of livestock ownership	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Milk production, kg × head^{-1} × day^{-1}										
Cows at agrienterprises	4.35	5.67	6.02	5.60	6.78	8.09	8.45	8.58	9.22	10.67
Cows at households	8.11	8.41	8.76	8.82	9.34	9.98	10.45	10.42	10.69	11.21
Fat content of milk, %										
Cows at agrienterprises	3.47	3.49	3.49	3.49	3.52	3.52	3.52	3.52	3.52	3.52
Cows at households	3.47	3.49	3.49	3.49	3.52	3.52	3.52	3.52	3.52	3.52

Type of livestock ownership	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Milk production, kg × head^{-1} × day^{-1}										
Cows at agrienterprises	10.89	10.48	11.97	12.39	13.23	14.11	14.93	15.87	16.11	16.40
Cows at households	11.26	11.61	11.77	12.02	12.24	12.39	12.35	12.52	12.86	13.09
Fat content of milk, %										
Cows at agrienterprises	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
Cows at households	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52

Type of livestock ownership	2020	2021
Milk production, kg × head^{-1} × day^{-1}		
Cows at agrienterprises	17.44	17.80
Cows at households	13.23	13.64
Fat content of milk, %		
Cows at agrienterprises	3.52	3.52
Cows at households	3.52	3.52

Table A3.2.2.7. Cattle average digestibility of the feed (DE), %

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agricultural enterprises										
Cows	68.66	68.31	67.84	67.89	67.70	67.65	67.56	67.60	67.69	67.72
Heifers from 2 years and older	65.19	64.88	64.58	64.57	64.37	64.30	64.24	64.31	64.31	64.33
Heifers from 1 to 2 years	66.91	66.78	66.51	66.55	66.45	66.37	66.30	66.33	66.34	66.36
Breeding bulls	70.56	70.28	69.79	69.91	69.76	69.60	69.44	69.50	69.50	69.52
Beef cows	65.49	64.84	64.44	64.37	64.05	64.00	63.96	64.19	64.18	64.16
Cows on fattening and feeding	66.72	66.27	65.86	65.81	65.49	65.44	65.42	65.61	65.63	65.63
Other cattle and beef cattle (without cows) on fattening and feeding	67.04	66.56	66.15	66.09	65.76	65.70	65.67	65.85	65.87	65.87
Other cattle	66.89	66.79	66.50	66.53	66.44	66.37	66.31	66.38	66.39	66.41
Households										
Cows	67.79	67.84	67.80	67.85	67.87	67.85	67.83	67.87	67.95	68.03
Heifers 2 years and older	67.76	67.86	67.82	67.90	67.94	67.89	67.83	67.70	67.74	67.77
Heifers from 1 to 2 years	66.37	66.50	66.43	66.51	66.55	66.52	66.49	66.33	66.46	66.58
Breeding bulls	69.23	69.27	69.25	69.26	69.29	69.27	69.24	69.28	69.34	69.41
Other cattle	66.42	66.54	66.47	66.54	66.57	66.53	66.50	66.35	66.48	66.62

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agricultural enterprises										
Cows	67.74	67.76	67.79	67.82	67.84	67.89	67.93	67.93	68.06	67.88
Heifers from 2 years and older	64.34	64.34	64.36	64.37	64.38	64.40	64.54	64.50	64.75	64.52
Heifers from 1 to 2 years	66.37	66.39	66.40	66.41	66.43	66.45	66.60	66.57	66.82	66.63
Breeding bulls	69.55	69.58	69.60	69.63	69.67	69.76	69.84	69.75	70.03	69.78
Beef cows	64.15	64.13	64.12	64.13	64.16	64.22	64.39	64.31	64.74	64.52
Cows on fattening and feeding	65.67	65.71	65.72	65.73	65.76	65.78	65.92	65.86	66.15	65.86
Other cattle and beef cattle (without cows) on fattening and feeding	65.90	65.93	65.93	65.95	65.98	66.01	66.17	66.11	66.41	66.14
Other cattle	66.43	66.46	66.48	66.49	66.53	66.56	66.70	66.67	66.93	66.75
Households										

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cows	68.12	68.21	68.30	68.40	68.49	68.57	68.54	68.55	68.54	68.57
Heifers 2 years and older	67.82	67.86	67.90	67.95	67.99	68.03	68.03	67.99	67.96	68.06
Heifers from 1 to 2 years	66.70	66.82	66.95	67.08	67.21	67.33	67.35	67.32	67.30	67.40
Breeding bulls	69.47	69.53	69.59	69.66	69.72	69.79	69.76	69.77	69.77	69.78
Other cattle	66.75	66.88	67.01	67.15	67.28	67.41	67.42	67.40	67.38	67.48

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agricultural enterprises										
Cows	67.87	67.91	67.82	67.65	67.48	67.50	67.38	67.46	67.37	67.39
Heifers from 2 years and older	64.56	64.62	64.64	64.61	64.30	64.25	64.21	64.11	63.21	63.37
Heifers from 1 to 2 years	66.68	66.75	66.77	66.77	66.52	66.50	66.57	66.47	65.62	65.72
Breeding bulls	69.80	69.89	69.72	69.57	69.30	69.27	69.15	69.31	68.59	68.69
Beef cows	64.42	64.67	64.77	64.54	63.97	63.79	62.94	62.89	61.20	61.35
Cows on fattening and feeding	65.89	65.98	65.99	65.95	65.54	65.48	65.37	65.24	64.07	64.28
Other cattle and beef cattle (without cows) on fattening and feeding	66.15	66.23	66.27	66.20	65.75	65.66	65.46	65.33	64.22	64.43
Other cattle	66.78	66.85	66.89	66.88	66.66	66.64	66.74	66.63	65.80	65.96
Households										
Cows	68.57	68.58	68.58	68.57	68.57	68.57	68.56	68.57	68.58	68.58
Heifers 2 years and older	68.08	68.13	68.14	68.11	68.15	68.15	68.14	68.13	68.20	68.19
Heifers from 1 to 2 years	67.41	67.46	67.47	67.43	67.46	67.45	67.45	67.44	67.51	67.52
Breeding bulls	69.78	69.79	69.79	69.78	69.78	69.77	69.77	69.77	69.78	69.78
Other cattle	67.49	67.53	67.54	67.51	67.54	67.53	67.53	67.52	67.59	67.59

Sex-age group	2020	2021
Agricultural enterprises		
Cows	67.32	67.31
Heifers from 2 years and older	63.09	63.12
Heifers from 1 to 2 years	65.51	65.50
Breeding bulls	68.44	68.48
Beef cows	60.87	60.96

Sex-age group	2020	2021
Cows on fattening and feeding	63.89	63.99
Other cattle and beef cattle (without cows) on fattening and feeding	64.02	64.10
Other cattle	65.76	65.71
Households		
Cows	68.58	68.57
Heifers 2 years and older	68.20	68.21
Heifers from 1 to 2 years	67.53	67.54
Breeding bulls	69.78	69.78
Other cattle	67.60	67.61

Table A3.2.2.8. Average weighted gross energy intake of sheep sex-age groups at all kinds of livestock owners, MJ × head $^{-1}$ × day $^{-1}$

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Ewes and young ewes 1 year and older	20.84	20.73	20.70	20.74	20.75	20.76	20.80	21.05	21.17	21.31
Breeding rams	31.19	31.16	31.13	31.13	31.10	30.97	30.94	31.00	30.97	31.00
Wethers (castrated rams)	17.72	17.69	17.66	17.66	17.63	17.57	17.54	17.60	17.57	17.60
Feeding livestock	19.70	19.67	19.64	19.64	19.61	19.55	19.52	19.58	19.55	19.58
Lambs to 4 months and Repair Lambs 4-12 months	19.07	19.04	19.01	19.01	18.98	18.92	18.89	18.95	18.92	18.95

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ewes and young ewes 1 year and older	21.60	21.84	21.91	21.61	22.89	22.17	22.39	22.56	22.31	21.68
Breeding rams	30.71	30.77	30.80	30.07	30.14	30.20	30.23	30.27	30.24	30.27
Wethers (castrated rams)	17.60	17.66	17.69	17.69	17.72	17.75	17.78	17.78	17.75	17.78
Feeding livestock	19.58	19.64	19.67	19.67	19.70	19.73	19.76	19.76	19.73	19.76
Lambs to 4 months and Repair Lambs 4-12 months	18.95	19.01	19.04	19.04	19.07	19.10	19.13	19.13	19.10	19.13

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ewes and young ewes 1 year and older	22.33	23.59	23.49	23.46	23.23	23.13	22.88	23.03	23.20	22.96
Breeding rams	30.26	30.41	30.39	30.36	30.35	30.33	30.31	30.30	30.27	30.27
Wethers (castrated rams)	17.72	17.72	17.69	17.66	17.64	17.63	17.61	17.60	17.57	17.57
Feeding livestock	19.70	19.70	19.67	19.64	19.62	19.61	19.59	19.58	19.55	19.54
Lambs to 4 months and Repair Lambs 4-12 months	19.07	19.07	19.04	19.01	19.00	18.98	18.96	18.95	18.92	18.92

Sex-age group	2020	2021
Ewes and young ewes 1 year and older	23.09	23.27
Breeding rams	30.30	30.36
Wethers (castrated rams)	17.59	17.65
Feeding livestock	19.57	19.63
Lambs to 4 months and Repair Lambs 4-12 months	18.95	19.01

Table A3.2.2.9. Source data for sheep gross energy estimation

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Average live weight, kg										
Ewes and young ewes 1 year and older	56.70	56.70	56.70	56.70	56.70	56.70	56.70	56.70	56.70	56.70
Breeding rams	109.30	109.30	109.30	109.30	109.30	109.00	109.00	109.00	109.00	109.00
Wethers (castrated rams)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Feeding livestock	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Lambs to 4 months and Repair Lambs 4-12 months	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20
Milk production, kg head^{-1} yr^{-1}										
The weighted average used for estimations (including of allowance of 60 kg in the lactation period)	75.0	73.0	73.0	74.0	75.0	77.0	79.0	84.0	88.0	91.0
Number of lambs born from one ewe										
Number of lambs born per one ewe	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Annual wool production per sheep, kg yr^{-1}										
Weighted average for agricultural enterprises and households	3.40	3.30	3.20	3.20	3.10	2.90	2.80	3.00	2.90	3.00

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Average live weight, kg										
Ewes and young ewes 1 year and older	57.10	57.10	57.10	55.90	56.00	56.10	56.10	56.20	56.20	56.20
Breeding rams	107.70	107.70	107.70	104.40	104.60	104.70	104.70	104.90	104.90	104.90
Wethers (castrated rams)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Feeding livestock	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Lambs to 4 months and Repair Lambs 4-12 months	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20
Milk production, kg/head per year										
The weighted average used for estimations (including of allowance of 60 kg in the lactation period)	96.0	101.0	102.0	102.0	135.0	114.0	119.0	123.0	117.0	99.0
Number of lambs born from one ewe										
Number of lambs born per one ewe	1.18	1.18	1.18	1.17	1.18	1.18	1.18	1.18	1.19	1.19
Annual wool production per sheep, kg/year										
Weighted average for agricultural enterprises and households	3.00	3.20	3.30	3.30	3.40	3.50	3.60	3.60	3.50	3.60

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Average live weight, kg										
Ewes and young ewes 1 year and older	56.40	57.00	57.01	57.01	57.01	57.01	57.01	57.01	57.01	57.01
Breeding rams	105.10	105.80	105.85	105.85	105.85	105.85	105.85	105.85	105.85	105.85
Wethers (castrated rams)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Feeding livestock	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Lambs to 4 months and Repair Lambs 4-12 months	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20	37.20
Milk production, kg/head per year										
The weighted average used for estimations (including of allowance of 60 kg in the lactation period)	117.00	147.00	145.00	145.00	139.11	136.79	130.45	134.91	140.37	133.84
Number of lambs born from one ewe										
Number of lambs born per one ewe	1.19	1.20	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Annual wool production per sheep, kg/year										
Weighted average for agricultural enterprises and households	3.40	3.40	3.30	3.20	3.15	3.09	3.04	3.01	2.91	2.90

Category	2020	2021
Average live weight, kg		
Ewes and young ewes 1 year and older	57.01	57.01
Breeding rams	105.85	105.85
Wethers (castrated rams)	60.00	60.00
Feeding livestock	42.50	42.50
Lambs to 4 months and Repair Lambs 4-12 months	37.20	37.20
Milk production, kg/head per year		
The weighted average used for estimations (including of allowance of 60 kg in the lactation period)	136.51	139.99
Number of lambs born from one ewe		
Number of lambs born per one ewe	1.21	1.21
Annual wool production per sheep, kg/year		
Weighted average for agricultural enterprises and households	2.98	3.18

Table A3.2.2.10. The typical live weight of sheep and the average number of lambs born from one ewe during the year by breeds and breed types

Breeds and breed types of sheep	Live weight of ewes, kg	Live weight of rams, kg	Number of lambs from one ewe
Wool-meat breeds of fine-wool sheep			
Askanian fine-wooled	58	125	1.25
Taurean type	60	120	1.27
Meat-wool breeds of fine-wool sheep			
Precoce	58	110	1.45
Kharkiv type	63	135	1.15
Transcarpathian type	66	128	1.15
Polvars	63	108	1.12
Wool-meat breeds of semi-finewool sheep			
Tsigai	55	90	1.30
Crimean type	57	104	1.03
Pre-Azov type	54	102	0.85
Meat-wool breeds for semi-finewool sheep			
Latvian dark face breed	63	113	1.40
Askanian meat and wool	58	114	1.24
Askanian cross-bred	65	128	1.42
Askanian type of Blackface sheep	69	138	1.52
Kharkiv type	54	88	1.28
Odessa type	60	102	1.12
Bukovyna type	57	119	1.19
Dnipropetrovsk type	54	103	1.18
Romney Marsh	68	125	1.25
Texel	100	68	0.93
North Caucasian	83	58	1.25
Fur-bearing breeds of coarse wool sheep			
Karakul	45	80	1.08
Askanian breed type of multiple lambing karakul sheep	60	92	1.86
Sokolska	43	65	1.23
Meat and wool dairy breeds of coarse wool sheep			
Ukrainian Carpatian mountain	39	63	1.10
Fur sheep			
Romanovska	52	71	2.50
Meat breeds			
Charolais	108	68	1.70
Olibs	110	68	2.20
Dairy breeds			
Ostfriesische	93	75	2.05

Table A3.2.2.11. The species composition of sheep in Ukraine, rel. u

Breeds	1990	1995	2000	2005	2010	2015	2020	2021
Tsigai and breed types	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Askanian meat and wool with cross-bred wool and breed types	0.01	0.04	0.16	0.17	0.17	0.17	0.17	0.17
Askanian fine-wool and the breed type	0.39	0.37	0.18	0.16	0.16	0.16	0.16	0.16
Prekos and breed types	0.11	0.11	0.17	0.13	0.13	0.13	0.13	0.13
Karakul	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03
Askanian breed type of multiple lambing karakul sheep	0.004	0.007	0.017	0.017	0.017	0.017	0.017	0.017
Sokolska	0.009	0.009	0.01	0.003	0.003	0.003	0.003	0.003
Ukrainian Carpatian mountain	0.03	0.03	0.03	0.08	0.08	0.08	0.08	0.08
Polvars	0.00004	0.0001	0.0003	0.0004	0.0003	0.0003	0.0003	0.0003
Romanovska	0.00008	0.0004	0.001	0.003	0.010	0.010	0.010	0.010
Latvian dark face	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008
Romney Marsh	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008
Charolais	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008
Olibs	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008
Ostfriesische	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008
Texel	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008
North Caucasian	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008	0.0008

Table A3.2.2.12. Live weight of repair growing sheep up to 1 year by breed, kg*

Category	4-6 months	6-8 months	8-10 months	10-12 months
Fine-wool				
Live weight	27.5	33	38	41
Semi-finewool				
Live weight	31.5	38.5	43	47.5
Average value of live weight	**38**			

* Gimmers' weight indicated, because repair rams used only at breeding farms, and their share is insignificant.

A3.2.3 Manure Management

Table A3.2.3.1. Excretion norms, ash content, and maximum methane-producing capacity of the manure

Sex-age group	Manure excretion in the dry matter (MDMex), kg/head per day	Ash content in manure (ASH), rel. u	Maximum methane-producing capacity of the manure (B_O), m^3 of CH_4 kg^{-1} of VS
Cattle at agrienterprises			
Cows	6.38	0.16	0.24
Heifers 2 years and older	4.26	0.16	0.24
Heifers from 1 to 2 years	3.59	0.16	0.17
Bulls	5.60	0.16	0.17
Beef cows	6.52	0.16	0.17
Cows on fattening	6.48	0.16	0.17
Cattle on fattening (excluding cows)	3.59	0.16	0.17
Other cattle	3.59	0.16	0.17
Cattle in households			
Cows	6.38	0.16	0.24
Heifers 2 years and older	4.26	0.16	0.24
Heifers from 1 to 2 years	3.59	0.16	0.17
Bulls	5.60	0.16	0.17
Other cattle	3.59	0.16	0.17
Sheep at all categories of farms			
Ewes and gimmers 1 year and older	1.20	0.074	0.19
Rams	1.50	0.074	0.19
Wethers	1.20	0.074	0.19
Fattening livestock	1.00	0.074	0.19
Lambs up to 4 months and 4-12 months replacement young sheep	0.70	0.074	0.19
Swine at agrienterprises			
Main sows	1.0015	0.15	0.45
Sows tested	0.8992	0.15	0.45
Repair swine 4 months and older	0.6509	0.15	0.45
Piglets up to 2 months	0.0718	0.15	0.45
Piglets 2 to 4 months	0.2409	0.15	0.45
Fattening swine	0.6985	0.15	0.45

Sex-age group	Manure excretion in the dry matter (MDMex), kg/head per day	Ash content in manure (ASH), rel. u	Maximum methane-producing capacity of the manure (B_O), m^3 of CH_4 kg^{-1} of VS
Boars	1.1672	0.15	0.45
Swine in households			
Main sows	1.3020	0.15	0.45
Repair swine 4 months and older	0.8461	0.15	0.45
Piglets up to 2 months	0.0933	0.15	0.45
Piglets 2 to 4 months	0.3132	0.15	0.45
Fattening swine	0.9081	0.15	0.45
Boars	1.5174	0.15	0.45
Poultry at all categories of farms			
Hens and roosters	0.043	0.173	0.39
Geese	0.113	0.173	0.36
Ducks	0.080	0.173	0.36
Turkeys	0.158	0.173	0.36
Other poultry		0.173	0.36

Table A3.2.3.2. Manure distribution by the manure management systems (MMS), rel. u

MMS types	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agrienterprises										
Liquid slurry	0.210	0.210	0.170	0.160	0.130	0.100	0.090	0.050	0.030	0.030
Solid storage	0.435	0.435	0.455	0.455	0.485	0.505	0.495	0.495	0.495	0.495
Pasture/Range/Paddock	0.350	0.350	0.370	0.380	0.380	0.390	0.410	0.450	0.470	0.470
Composting	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cattle in households										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sheep at all categories of farms										
Solid storage	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Pasture/paddock	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Swine at agrienterprises										
Uncovered anaerobic lagoon	NO	NO	NO	NO	NO	0.060	0.065	0.075	0.075	0.075
Liquid slurry	0.370	0.342	0.292	0.242	0.195	0.160	0.135	0.125	0.125	0.125
Solid storage	0.575	0.605	0.656	0.700	0.750	0.775	0.795	0.795	0.795	0.795
Composting	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Aerobic treatment	0.050	0.048	0.047	0.053	0.050	NO	NO	NO	NO	NO
Swine in households										
Solid storage	1	1	1	1	1	1	1	1	1	1
Fur-bearing animals										
Solid storage	1	1	1	1	1	1	1	1	1	1
Rabbits										
Solid storage	1	1	1	1	1	1	1	1	1	1
Buffaloes										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Goats										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Camels										
Pasture/Range/Paddock	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Other systems	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

MMS types	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Horses										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Asses and mules										
Pasture/Range/Paddock	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Other systems	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Poultry at agrienterprises										
Poultry manure without litter	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992
Composting	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Poultry in households										
Poultry manure without litter	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

MMS types	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agrienterprises										
Liquid slurry	0.010	0.010	0.010	0.010	0.010	0.010	0.030	0.030	0.040	0.041
Solid storage	0.495	0.495	0.495	0.495	0.495	0.495	0.485	0.485	0.475	0.475
Pasture/Range/Paddock	0.490	0.490	0.490	0.490	0.490	0.490	0.480	0.480	0.480	0.479
Composting	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cattle in households										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sheep at all categories of farms										
Solid storage	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Pasture/Range/Paddock	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Swine at agrienterprises										
Uncovered anaerobic lagoon	0.080	0.080	0.080	0.080	0.080	0.100	0.100	0.120	0.140	0.140
Liquid slurry	0.110	0.120	0.160	0.180	0.170	0.210	0.160	0.160	0.200	0.250
Solid storage	0.805	0.795	0.755	0.735	0.745	0.685	0.735	0.715	0.655	0.605
Composting	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Aerobic treatment	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Swine in households										

MMS types	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Solid storage	1	1	1	1	1	1	1	1	1	1
Fur-bearing animals										
Solid storage	1	1	1	1	1	1	1	1	1	1
Rabbits										
Solid storage	1	1	1	1	1	1	1	1	1	1
Buffaloes										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Goats										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Camels										
Pasture/paddock	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Other systems	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Horses										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Asses and mules										
Pasture/Range/Paddock	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Other systems	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Poultry at agrienterprises										
Poultry manure without litter	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992
Composting	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Poultry in households										
Poultry manure without litter	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

MMS types	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle at agrienterprises										
Liquid slurry	0.044	0.040	0.042	0.045	0.047	0.049	0.052	0.049	0.051	0.053
Solid storage	0.476	0.477	0.473	0.471	0.466	0.463	0.460	0.458	0.459	0.456

MMS types	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Pasture/Range/Paddock	0.478	0.480	0.479	0.478	0.476	0.475	0.474	0.475	0.475	0.474
Composting	0.002	0.003	0.006	0.007	0.010	0.013	0.015	0.018	0.015	0.018
Cattle in households										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sheep at all categories of farms										
Solid storage	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Pasture/Range/Paddock	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Swine at agrienterprises										
Uncovered anaerobic lagoon	0.140	0.140	0.150	0.125	0.097	0.080	0.062	0.078	0.063	0.046
Liquid slurry	0.310	0.370	0.360	0.397	0.436	0.460	0.483	0.459	0.484	0.509
Solid storage	0.548	0.487	0.484	0.471	0.457	0.448	0.441	0.446	0.438	0.427
Composting	0.002	0.003	0.006	0.007	0.010	0.013	0.015	0.018	0.015	0.018
Aerobic treatment	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Swine in households										
Solid storage	1	1	1	1	1	1	1	1	1	1
Fur-bearing animals										
Solid storage	1	1	1	1	1	1	1	1	1	1
Rabbits										
Solid storage	1	1	1	1	1	1	1	1	1	1
Buffaloes										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Goats										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Camels										
Pasture/Range/Paddock	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Other systems	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Horses										
Solid storage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Asses and mules										

MMS types	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Pasture/Range/Paddock	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Other systems	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Poultry at agrienterprises										
Poultry manure without litter	0.993	0.990	0.994	0.992	0.968	0.998	0.995	0.995	0.997	0.998
Composting	0.007	0.010	0.006	0.008	0.032	0.002	0.005	0.005	0.003	0.002
Poultry in households										
Poultry manure without litter	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pasture/Range/Paddock	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

MMS types	2020	2021
Cattle at agrienterprises		
Liquid slurry	0.054	0.056
Solid storage	0.456	0.455
Pasture/Range/Paddock	0.473	0.472
Composting	0.017	0.016
Cattle in households		
Solid storage	0.5	0.5
Pasture/Range/Paddock	0.5	0.5
Sheep at all categories of farms		
Solid storage	0.26	0.26
Pasture/Range/Paddock	0.74	0.74
Swine at agrienterprises		
Uncovered anaerobic lagoon	0.044	0.050
Liquid slurry	0.523	0.523
Solid storage	0.417	0.411
Composting	0.017	0.016
Aerobic treatment	NO	NO
Swine in households		
Solid storage	1	1
Fur-bearing animals		
Solid storage	1	1
Rabbits		

MMS types	2020	2021
Solid storage	1	1
Buffaloes		
Solid storage	0.5	0.5
Pasture/Range/Paddock	0.5	0.5
Goats		
Solid storage	0.5	0.5
Pasture/Range/Paddock	0.5	0.5
Camels		
Pasture/Range/Paddock	0.92	0.92
Other systems	0.08	0.08
Horses		
Solid storage	0.5	0.5
Pasture/Range/Paddock	0.5	0.5
Asses and mules		
Pasture/Range/Paddock	0.92	0.92
Other systems	0.08	0.08
Poultry at agrienterprises		
Poultry manure without litter	0.999992	0.999993
Composting	0.000008	0.000007
Poultry in households		
Poultry manure without litter	0.5	0.5
Pasture/Range/Paddock	0.5	0.5

Table A3.2.3.3. Daily volatile solids (VS), kg dry matter animal^{-1} day^{-1}

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agricultural enterprises										
Cows	3.26	3.21	3.10	3.07	3.07	3.03	2.97	2.85	2.93	2.96
Heifers 2 years and older	2.64	2.69	2.73	2.73	2.76	2.77	2.78	2.77	2.77	2.76
Heifers from 1 to 2 years	2.08	2.09	2.12	2.12	2.13	2.14	2.14	2.14	2.14	2.14
Bulls	2.48	2.51	2.57	2.56	2.58	2.60	2.62	2.61	2.61	2.61
Beef cows	2.02	2.08	2.12	2.13	2.16	2.17	2.17	2.15	2.15	2.15
Cows on fattening	3.66	3.75	3.83	3.84	3.91	3.92	3.92	3.88	3.88	3.88
Other cattle and beef cattle fattening	1.70	1.74	1.78	1.78	1.81	1.82	1.82	1.81	1.80	1.80
Other cattle	1.51	1.52	1.54	1.54	1.55	1.55	1.56	1.55	1.55	1.55
Cattle at households										
Cows	3.53	3.53	3.52	3.52	3.52	3.54	3.54	3.56	3.57	3.57
Heifers 2 years and older	2.49	2.48	2.48	2.47	2.47	2.48	2.48	2.50	2.49	2.49
Heifers from 1 to 2 years	2.24	2.22	2.23	2.22	2.22	2.22	2.23	2.24	2.23	2.22
Bulls	2.61	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.59	2.58
Other cattle	1.79	1.78	1.79	1.78	1.78	1.78	1.79	1.80	1.79	1.78
Sheep at all categories of farms										
Ewes and gimmers 1 year and older	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.39
Rams	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Wethers	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Fattening livestock	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Lambs up to 4 months and 4-12 months replacement young sheep	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Swine at agricultural enterprises										
Main sows	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Sows tested	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Repair swine 4 months and older	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Piglets up to 2 months	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Piglets 2 to 4 months	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fattening swine	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Boars	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Swine at households										
Main sows	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Repair swine 4 months and older	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Piglets up to 2 months	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Piglets 2 to 4 months	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Fattening swine	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Boars	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
Poultry at all categories of farms										
Hens and roosters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Geese	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Ducks	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Turkeys	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other poultry	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agricultural enterprises										
Cows	2.91	3.09	3.13	3.07	3.22	3.39	3.43	3.45	3.51	3.74
Heifers 2 years and older	2.76	2.76	2.76	2.76	2.76	2.75	2.73	2.74	2.70	2.74
Heifers from 1 to 2 years	2.14	2.13	2.13	2.13	2.13	2.13	2.11	2.12	2.09	2.11
Bulls	2.60	2.60	2.60	2.59	2.59	2.58	2.57	2.58	2.54	2.57
Beef cows	2.15	2.15	2.16	2.16	2.15	2.15	2.13	2.14	2.09	2.12
Cows on fattening	3.87	3.86	3.86	3.86	3.85	3.85	3.82	3.83	3.77	3.83
Other cattle and beef cattle fattening	1.80	1.80	1.80	1.80	1.79	1.79	1.78	1.78	1.75	1.78
Other cattle	1.55	1.54	1.54	1.54	1.54	1.54	1.52	1.53	1.51	1.52
Cattle at households										
Cows	3.60	3.62	3.65	3.64	3.70	3.77	3.84	3.83	3.87	3.93
Heifers 2 years and older	2.48	2.48	2.47	2.47	2.46	2.46	2.46	2.46	2.47	2.45
Heifers from 1 to 2 years	2.20	2.19	2.17	2.16	2.15	2.13	2.13	2.13	2.14	2.13
Bulls	2.58	2.57	2.56	2.55	2.54	2.54	2.54	2.54	2.54	2.54
Other cattle	1.76	1.75	1.74	1.73	1.72	1.70	1.70	1.71	1.71	1.70
Sheep at all categories of farms										

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ewes and gimmers 1 year and older	0.40	0.40	0.40	0.40	0.42	0.41	0.41	0.41	0.41	0.40
Rams	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Wethers	0.32	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33
Fattening livestock	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Lambs up to 4 months and 4-12 months replacement young sheep	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Swine at agricultural enterprises										
Main sows	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Sows tested	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Repair swine 4 months and older	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Piglets up to 2 months	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Piglets 2 to 4 months	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fattening swine	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Boars	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Swine at households										
Main sows	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Repair swine 4 months and older	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Piglets up to 2 months	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Piglets 2 to 4 months	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Fattening swine	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Boars	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
Poultry at all categories of farms										
Hens and roosters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Geese	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Ducks	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Turkeys	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other poultry	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle at agricultural enterprises										
Cows	3.77	3.71	3.92	4.01	4.16	4.27	4.41	4.52	4.57	4.61
Heifers 2 years and older	2.73	2.72	2.72	2.72	2.77	2.77	2.78	2.79	2.93	2.90
Heifers from 1 to 2 years	2.10	2.10	2.09	2.09	2.12	2.12	2.11	2.13	2.22	2.21
Bulls	2.57	2.56	2.58	2.60	2.63	2.64	2.65	2.63	2.73	2.71
Beef cows	2.13	2.10	2.09	2.11	2.17	2.19	2.28	2.29	2.48	2.46
Cows on fattening	3.83	3.81	3.81	3.81	3.90	3.91	3.93	3.96	4.21	4.17
Other cattle and beef cattle fattening	1.78	1.77	1.77	1.77	1.82	1.82	1.84	1.85	1.96	1.94
Other cattle	1.52	1.51	1.51	1.51	1.53	1.53	1.52	1.53	1.60	1.58
Cattle at households										
Cows	3.94	3.98	4.00	4.04	4.06	4.08	4.08	4.10	4.14	4.18
Heifers 2 years and older	2.45	2.44	2.44	2.45	2.44	2.44	2.44	2.45	2.44	2.44
Heifers from 1 to 2 years	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.11	2.11
Bulls	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
Other cattle	1.70	1.69	1.69	1.70	1.69	1.69	1.70	1.70	1.69	1.69
Sheep at all categories of farms										
Ewes and gimmers 1 year and older	0.41	0.43	0.43	0.43	0.43	0.42	0.42	0.42	0.43	0.42
Rams	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.55	0.55
Wethers	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Fattening livestock	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Lambs up to 4 months and 4-12 months replacement young sheep	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Swine at agricultural enterprises										
Main sows	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Sows tested	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Repair swine 4 months and older	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Piglets up to 2 months	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Piglets 2 to 4 months	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fattening swine	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Boars	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Swine at households										

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Main sows	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Repair swine 4 months and older	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Piglets up to 2 months	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Piglets 2 to 4 months	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Fattening swine	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Boars	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
Poultry at all categories of farms										
Hens and roosters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Geese	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Ducks	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Turkeys	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Other poultry	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Sex-age group	2020	2021
Cattle at agricultural enterprises		
Cows	4.77	4.82
Heifers 2 years and older	2.95	2.94
Heifers from 1 to 2 years	2.23	2.23
Bulls	2.75	2.74
Beef cows	2.52	2.51
Cows on fattening	4.25	4.23
Other cattle and beef cattle fattening	1.98	1.98
Other cattle	1.60	1.60
Cattle at households		
Cows	4.19	4.25
Heifers 2 years and older	2.44	2.43
Heifers from 1 to 2 years	2.11	2.11
Bulls	2.54	2.54
Other cattle	1.69	1.69
Sheep at all categories of farms		

Sex-age group	2020	2021
Ewes and gimmers 1 year and older	0.42	0.43
Rams	0.56	0.56
Wethers	0.32	0.32
Fattening livestock	0.36	0.36
Lambs up to 4 months and 4-12 months replacement young sheep	0.35	0.35
Swine at agricultural enterprises		
Main sows	0.85	0.85
Sows tested	0.76	0.76
Repair swine 4 months and older	0.55	0.55
Piglets up to 2 months	0.06	0.06
Piglets 2 to 4 months	0.20	0.20
Fattening swine	0.59	0.59
Boars	0.99	0.99
Swine at households		
Main sows	1.11	1.11
Repair swine 4 months and older	0.72	0.72
Piglets up to 2 months	0.08	0.08
Piglets 2 to 4 months	0.27	0.27
Fattening swine	0.77	0.77
Boars	1.29	1.29
Poultry at all categories of farms		
Hens and roosters	0.04	0.04
Geese	0.09	0.09
Ducks	0.07	0.07
Turkeys	0.13	0.13
Other poultry	0.10	0.10

Table A3.2.3.4. Annual average N excretion per head of cattle and fur-bearing animals, kg N animal^{-1} yr^{-1}

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agricultural enterprises										
Dairy cows	57.21	55.35	52.54	52.81	54.76	51.21	47.92	41.64	43.53	45.58
Heifers 2 years and older	36.96	36.17	35.13	36.21	37.65	35.95	34.24	30.73	31.83	32.92
Heifers from 1 to 2 years	30.11	29.38	28.66	29.47	30.53	29.18	27.82	25.01	25.88	26.76
Bulls	40.46	39.86	39.77	40.20	41.13	39.83	38.50	35.18	36.38	37.51
Beef cows	33.30	32.83	32.27	33.36	34.49	32.90	31.31	28.20	29.09	29.98
Cows on fattening	45.63	44.90	43.33	44.64	46.18	44.19	42.22	38.16	39.60	41.02
Other cattle and beef cattle fattening	18.06	17.78	17.26	17.88	18.67	17.78	16.88	14.85	15.48	16.11
Other cattle	16.52	16.10	15.69	16.26	16.89	16.09	15.23	13.29	13.82	14.39
Cattle at households										
Dairy cows	38.07	37.28	38.26	37.83	38.12	38.60	39.10	39.09	40.00	40.82
Heifers 2 years and older	27.24	26.66	26.73	26.19	26.59	27.36	28.14	29.20	29.77	30.34
Heifers from 1 to 2 years	23.11	22.63	22.75	22.20	22.58	23.10	23.62	24.53	25.05	25.57
Bulls	32.38	31.99	32.18	32.15	32.26	32.58	32.90	32.84	33.55	34.26
Other cattle	13.48	13.22	13.34	13.01	13.43	13.94	14.42	15.07	15.44	15.83
Fur-bearing animals at all categories of farms										
Fur-bearing animals	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agricultural enterprises										
Dairy cows	47.31	50.22	52.51	54.14	57.35	60.78	63.75	62.33	67.27	77.62
Heifers 2 years and older	34.02	35.12	36.21	37.32	38.36	39.45	40.92	40.27	41.11	44.97
Heifers from 1 to 2 years	27.63	28.51	29.38	30.24	31.10	32.00	32.96	32.61	33.37	36.59
Bulls	38.64	39.76	40.88	42.00	43.12	44.02	44.49	44.04	45.31	49.57
Beef cows	30.87	31.76	32.65	33.58	34.62	35.70	36.04	35.03	36.04	39.63
Cows on fattening	42.46	43.88	45.25	46.61	47.96	49.31	50.76	50.24	51.38	56.18
Other cattle and beef cattle fattening	16.71	17.30	17.91	18.52	19.13	19.78	20.36	20.09	20.50	22.80
Other cattle	14.97	15.52	16.05	16.59	17.07	17.56	18.20	18.02	18.41	20.59
Cattle at households										
Dairy cows	41.67	42.54	43.43	44.24	45.23	46.28	45.21	45.49	45.25	46.43
Heifers 2 years and older	30.90	31.46	32.02	32.58	33.14	33.69	33.75	33.49	33.28	34.00

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Heifers from 1 to 2 years	26.08	26.60	27.10	27.61	28.11	28.61	28.73	28.67	28.61	29.11
Bulls	34.98	35.69	36.40	37.10	37.81	38.51	37.96	38.11	38.00	38.43
Other cattle	16.22	16.61	17.00	17.39	17.77	18.15	18.19	18.10	18.04	18.35
Fur-bearing animals at all categories of farms										
Fur-bearing animals	4.67	4.67	4.67	4.67	4.74	4.73	4.71	4.68	4.66	4.66

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle at agricultural enterprises										
Dairy cows	78.50	78.08	88.12	91.39	97.82	104.41	105.28	108.75	145.08	143.22
Heifers 2 years and older	43.57	42.81	45.09	44.84	47.03	48.55	48.03	48.57	65.33	64.68
Heifers from 1 to 2 years	35.39	34.75	36.53	36.43	38.43	39.50	38.77	39.43	53.20	52.74
Bulls	49.24	48.97	52.67	53.66	55.80	57.74	57.34	57.92	73.77	72.44
Beef cows	38.63	37.02	39.52	40.36	41.37	42.91	44.13	44.52	60.15	59.32
Cows on fattening	54.43	53.24	56.22	56.27	59.31	61.10	60.31	61.28	82.46	81.57
Other cattle and beef cattle fattening	21.95	21.31	22.67	22.74	24.18	25.05	24.83	25.24	35.35	34.89
Other cattle	19.64	19.35	20.44	20.40	21.94	22.63	21.92	22.49	31.91	31.63
Cattle at households										
Dairy cows	46.47	47.11	47.08	46.67	46.56	46.38	46.18	46.36	47.15	47.01
Heifers 2 years and older	34.15	34.51	34.66	34.52	34.72	34.71	34.64	34.58	35.00	34.98
Heifers from 1 to 2 years	29.12	29.31	29.30	29.12	29.25	29.21	29.18	29.15	29.48	29.51
Bulls	38.43	38.63	38.59	38.37	38.30	38.21	38.11	38.14	38.39	38.29
Other cattle	18.39	18.53	18.56	18.47	18.55	18.54	18.53	18.50	18.70	18.70
Fur-bearing animals at all categories of farms										
Fur-bearing animals	4.66	4.65	4.64	4.65	4.64	4.64	4.65	4.63	4.62	4.61

Sex-age group	2020	2021
Cattle at agricultural enterprises		
Dairy cows	147.86	148.80
Heifers 2 years and older	65.53	64.52
Heifers from 1 to 2 years	53.36	52.57
Bulls	72.00	72.78
Beef cows	59.34	58.57
Cows on fattening	83.10	81.53

Sex-age group	2020	2021
Other cattle and beef cattle fattening	35.59	34.88
Other cattle	32.15	31.65
Cattle at households		
Dairy cows	47.10	46.86
Heifers 2 years and older	34.99	34.99
Heifers from 1 to 2 years	29.63	29.71
Bulls	38.31	38.16
Other cattle	18.73	18.76
Fur-bearing animals at all categories of farms		
Fur-bearing animals	4.60	4.59

Table A3.2.3.5. Proportions of nitrogen in manure dry matter and the amount of nitrogen excreted as part of manure of swine, poultry and sheep

Sex-age groups	Proportion of nitrogen in manure dry matter (f_n), rel. u	Amount of nitrogen excreted (N_{ex}), kg head^{-1} yr^{-1}
Swine at agrienterprises		
Main sows	0.06	21.93
Sows tested	0.06	19.69
Repair swine 4 months and older	0.06	14.25
Piglets up to 2 months	0.06	1.57
Piglets 2 to 4 months	0.06	5.28
Fattening swine	0.06	15.30
Boars	0.06	25.56
Swine in households		
Main sows	0.06	28.51
Repair swine 4 months and older	0.06	18.53
Piglets up to 2 months	0.06	2.04
Piglets 2 to 4 months	0.06	6.86
Fattening swine	0.06	19.89
Boars	0.06	33.23
Poultry at all categories of farms		
Hens and roosters	0.018	0.28
Geese	0.007	0.29
Ducks	0.0095	0.28
Turkeys	0.0085	0.49
Other poultry	–	0.60
Sheep at all categories of farms		
Ewes and gimmers 1 year and older	0.023	10.07
Rams	0.023	12.59
Fattening livestock	0.023	10.07
Wethers	0.023	8.40
Lambs up to 4 months and 4-12 months repair young sheep	0.023	5.88

Table A3.2.3.6. Cattle fodder consumption at all types of livestock owners, kt

Kind of feeds	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agricultural enterprises										
Cows										
Concentrated feeds	6 403,25	5 776,76	4 362,99	4 222,48	4 062,94	3 062,22	2 262,87	1 354,28	1 401,82	1 189,33
Succulent feeds	70 631,92	71 729,01	62 503,52	58 884,42	53 554,67	46 700,02	40 704,15	34 373,10	31 298,23	23 521,92
Coarse feeds	9 746,96	9 938,61	10 128,08	9 314,79	9 026,28	8 042,04	7 151,35	5 736,20	5 314,95	4 020,44
Other feeds	28 231,07	22 948,51	16 810,57	15 890,29	13 017,78	11 765,73	10 122,53	8 919,62	8 698,58	6 586,08
Heifers 2 years and older										
Concentrated feeds	826,55	756,74	641,44	657,03	664,50	536,25	399,72	255,58	232,06	216,34
Succulent feeds	8 520,41	8 926,26	8 575,67	8 200,84	7 863,26	7 259,36	6 293,00	5 450,14	4 441,73	3 737,53
Coarse feeds	1 562,60	1 646,35	1 798,53	1 697,15	1 706,98	1 594,46	1 396,83	1 135,47	930,01	786,86
Other feeds	3 880,59	3 163,79	2 983,24	2 687,91	2 243,36	2 089,63	1 821,52	1 602,76	1 298,46	1 088,17
Heifers from 1 to 2 years										
Concentrated feeds	254,91	238,47	198,26	190,12	190,21	159,86	120,04	73,62	67,00	64,80
Succulent feeds	2 494,09	2 672,06	2 501,86	2 238,37	2 121,84	2 043,13	1 785,15	1 483,00	1 212,94	1 061,40
Coarse feeds	442,39	478,26	508,81	447,92	444,18	434,16	384,21	300,77	247,59	218,37
Other feeds	1 254,32	1 049,78	964,84	813,41	674,78	657,71	581,22	493,81	402,84	351,57
Bulls										
Concentrated feeds	7,41	7,29	6,48	6,46	6,35	5,22	4,37	3,10	3,16	3,34
Succulent feeds	66,10	73,86	74,74	69,65	66,09	63,16	62,99	64,12	56,66	52,67
Coarse feeds	9,32	10,53	12,37	11,30	11,03	11,16	11,70	11,26	10,11	9,53
Other feeds	40,12	36,95	32,97	32,34	27,89	27,21	27,60	28,55	25,35	23,92
Beef cows										
Concentrated feeds	8,33	8,90	8,27	9,25	16,11	23,74	24,91	19,51	21,37	23,23
Succulent feeds	73,56	90,22	92,30	94,92	157,58	266,56	326,93	348,48	344,78	340,23
Coarse feeds	17,87	22,11	25,69	25,88	43,69	76,81	97,47	98,18	98,30	98,35
Other feeds	44,93	43,90	43,41	42,65	63,23	109,67	137,49	151,55	150,88	150,07
Cows on fattening										
Concentrated feeds	303,96	276,00	228,52	228,81	218,42	172,38	130,85	83,99	75,65	71,15
Succulent feeds	3 245,80	3 368,26	3 193,38	2 978,73	2 734,62	2 466,68	2 180,67	1 907,22	1 547,56	1 318,12
Coarse feeds	714,29	732,86	789,92	732,67	699,84	635,72	561,92	449,48	364,36	311,18
Other feeds	1 475,12	1 195,86	1 101,02	976,10	774,44	707,79	634,20	567,24	458,59	387,77
Other cattle and beef cattle on fattening										

Kind of feeds	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Concentrated feeds	1 094,29	994,62	824,77	824,97	789,57	627,47	479,85	310,72	282,50	267,68
Succulent feeds	10 156,12	10 539,36	9 983,76	9 290,46	8 534,00	7 724,13	6 834,50	5 986,42	4 890,04	4 194,02
Coarse feeds	2 229,20	2 290,34	2 471,03	2 291,58	2 197,90	2 013,78	1 795,07	1 450,60	1 188,81	1 025,86
Other feeds	5 299,13	4 302,74	3 962,76	3 508,73	2 793,65	2 573,30	2 324,03	2 098,41	1 715,59	1 465,11
Other cattle										
Concentrated feeds	3 180,43	2 789,38	2 229,77	2 145,78	1 853,05	1 227,86	865,25	467,04	530,21	368,47
Succulent feeds	28 771,81	28 649,56	26 280,91	23 438,01	19 569,20	14 709,20	12 050,96	8 769,54	9 081,75	5 704,09
Coarse feeds	5 285,99	5 211,75	5 448,04	4 848,87	4 184,73	3 189,81	2 634,95	1 778,35	1 833,44	1 160,52
Other feeds	14 968,37	11 723,82	10 308,48	8 842,79	6 407,86	4 979,17	4 180,99	3 200,29	3 163,84	2 007,17
Cattle at households										
Cows										
Concentrated feeds	509,51	544,47	640,70	671,15	727,87	785,73	841,72	825,51	844,03	857,96
Succulent feeds	16 632,47	18 594,75	20 269,25	21 665,78	22 759,71	23 798,30	24 694,92	23 855,46	21 885,11	19 905,70
Coarse feeds	3 868,27	4 143,41	4 376,70	4 730,21	5 020,49	5 232,91	5 430,93	5 289,54	5 517,53	5 759,87
Other feeds	14 319,74	15 886,22	16 412,69	18 265,94	19 477,27	20 045,88	20 516,23	20 359,24	21 704,69	23 121,43
Heifers 2 years and older										
Concentrated feeds	21,35	23,21	27,34	28,64	29,68	28,29	27,52	29,34	31,85	34,45
Succulent feeds	398,84	437,22	520,20	559,81	542,66	489,70	452,39	460,59	451,30	436,96
Coarse feeds	66,13	72,70	84,51	88,92	86,72	84,61	84,30	87,15	98,70	111,20
Other feeds	396,80	479,01	539,19	614,67	615,49	560,17	521,41	478,87	547,42	621,39
Heifers from 1 to 2 years										
Concentrated feeds	48,17	52,33	63,55	69,21	74,06	67,90	59,79	58,83	60,52	64,22
Succulent feeds	842,85	926,97	1 134,41	1 279,19	1 275,62	1 112,46	932,25	871,39	808,51	766,96
Coarse feeds	130,23	143,54	173,19	190,03	191,24	179,16	160,65	153,10	164,76	182,40
Other feeds	930,14	1 112,07	1 288,67	1 514,66	1 550,07	1 366,72	1 159,00	988,88	1 069,62	1 190,45
Bulls										
Concentrated feeds	0,62	0,68	0,95	1,22	1,40	1,53	1,45	1,43	1,66	1,80
Succulent feeds	15,87	17,46	23,13	29,69	33,27	34,76	31,79	31,15	32,82	32,10
Coarse feeds	3,42	3,60	4,58	5,98	6,87	7,21	6,61	6,39	7,72	8,69
Other feeds	15,59	17,12	21,31	28,12	32,76	33,56	30,06	29,91	36,91	42,42
Other cattle										
Concentrated feeds	590,12	511,41	282,24	277,09	271,19	233,19	226,65	236,82	232,31	233,64
Succulent feeds	10 455,81	8 992,50	5 011,87	5 003,94	4 484,84	3 643,96	3 363,94	3 375,82	3 002,10	2 705,16

Kind of feeds	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Coarse feeds	1 501,65	1 309,19	733,39	717,44	653,08	578,07	578,62	589,34	605,15	634,95
Other feeds	11 442,71	10 705,92	5 712,10	5 942,10	5 422,14	4 457,20	4 179,82	3 839,17	3 999,03	4 234,71

Kind of feeds	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agricultural enterprises										
Cows										
Concentrated feeds	987,39	1 031,23	1 042,40	818,87	795,69	853,62	855,26	702,30	753,06	880,54
Succulent feeds	17 528,47	16 589,45	15 211,50	10 908,69	9 735,85	9 619,21	8 893,90	7 633,26	7 183,44	6 739,95
Coarse feeds	3 015,86	2 874,71	2 657,45	1 922,12	1 731,52	1 713,45	1 494,33	1 325,87	1 113,00	1 229,55
Other feeds	4 919,15	4 658,43	4 307,01	3 110,53	2 792,76	2 803,13	2 420,05	2 189,91	1 911,09	1 675,30
Heifers 2 years and older										
Concentrated feeds	191,85	177,81	174,39	158,16	138,38	126,82	120,86	100,73	95,95	99,65
Succulent feeds	3 022,02	2 574,04	2 317,15	1 939,92	1 578,36	1 338,02	1 147,66	994,45	880,19	744,98
Coarse feeds	639,20	546,76	495,14	416,72	341,57	293,63	239,31	210,13	165,10	164,82
Other feeds	872,69	735,38	659,04	546,76	444,81	383,49	324,70	283,25	247,12	205,96
Heifers from 1 to 2 years										
Concentrated feeds	60,08	61,63	65,66	60,19	52,97	50,47	52,14	46,50	47,01	52,51
Succulent feeds	898,01	846,13	829,07	702,70	574,27	506,92	476,81	440,09	411,25	373,42
Coarse feeds	186,05	176,42	174,33	148,85	122,45	109,17	96,54	89,89	74,10	79,71
Other feeds	296,42	278,19	271,79	229,61	187,50	166,78	151,52	137,30	124,11	110,61
Bulls										
Concentrated feeds	3,36	3,18	3,20	2,90	2,53	2,56	2,74	2,20	1,91	2,10
Succulent feeds	47,06	40,11	36,27	29,83	23,77	21,97	22,58	18,95	14,26	12,46
Coarse feeds	8,59	7,38	6,77	5,64	4,54	4,21	3,98	3,53	2,49	2,50
Other feeds	21,63	18,63	17,12	14,31	11,55	11,22	10,37	9,14	7,27	5,91
Beef cows										
Concentrated feeds	25,15	27,12	29,05	31,06	33,96	36,83	38,18	32,70	31,34	33,60
Succulent feeds	336,75	333,90	329,09	323,12	320,63	313,88	313,51	294,46	247,70	204,30
Coarse feeds	98,56	98,86	98,89	99,06	101,30	102,99	95,18	89,11	71,65	68,79
Other feeds	149,43	148,89	148,02	148,56	153,93	159,74	156,96	143,11	134,39	118,05
Cows on fattening										

Kind of feeds	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Concentrated feeds	61,67	54,40	53,08	46,89	39,42	36,87	37,13	31,86	30,02	30,91
Succulent feeds	1 054,60	869,89	781,82	640,50	504,94	438,13	401,49	358,39	314,27	264,59
Coarse feeds	246,96	201,10	181,54	149,17	117,49	103,17	89,47	80,31	62,09	61,19
Other feeds	307,91	252,65	225,65	184,27	146,10	128,53	114,97	100,45	86,14	71,21
Other cattle and beef cattle on fattening										
Concentrated feeds	235,41	210,95	207,24	186,45	162,49	156,25	158,63	136,17	128,93	133,13
Succulent feeds	3 384,63	2 809,84	2 541,03	2 113,71	1 710,76	1 519,29	1 413,17	1 268,14	1 106,15	926,76
Coarse feeds	828,92	687,93	627,25	525,94	428,80	385,68	337,77	304,97	238,02	234,18
Other feeds	1 183,18	987,43	890,38	742,86	610,21	551,70	502,78	443,17	386,91	324,43
Other cattle										
Concentrated feeds	264,12	309,74	347,80	226,47	231,94	283,45	308,32	244,77	231,24	286,18
Succulent feeds	3 729,40	4 044,50	4 201,93	2 539,53	2 456,49	2 832,57	2 785,23	2 287,78	2 005,19	2 048,04
Coarse feeds	762,87	825,86	862,97	524,81	503,28	575,96	534,72	440,78	336,10	406,65
Other feeds	1 311,25	1 396,16	1 455,32	881,83	822,79	910,80	866,45	686,72	559,26	554,98
Cattle at households										
Cows										
Concentrated feeds	896,56	950,74	1 011,63	1 005,20	983,35	989,71	915,42	841,41	785,91	785,21
Succulent feeds	18 393,82	17 025,76	15 564,77	13 004,22	10 403,74	8 208,92	8 643,86	7 709,53	7 446,85	6 709,49
Coarse feeds	6 161,87	6 678,72	7 259,06	7 359,74	7 352,81	7 562,02	7 560,78	6 822,67	6 503,27	6 104,54
Other feeds	25 236,06	27 865,44	30 798,24	31 714,37	32 063,24	33 274,40	33 223,74	29 975,74	28 587,23	26 859,96
Heifers 2 years and older										
Concentrated feeds	34,06	33,27	34,79	33,04	29,22	27,55	27,82	26,38	24,11	25,51
Succulent feeds	378,89	319,79	285,53	224,97	158,81	113,59	114,37	112,12	104,97	100,94
Coarse feeds	113,43	114,04	123,34	120,74	109,77	106,76	106,57	105,90	100,08	91,10
Other feeds	642,06	653,27	711,23	701,98	643,90	627,30	625,68	609,62	567,95	545,74
Heifers from 1 to 2 years										
Concentrated feeds	66,04	69,23	74,81	69,27	57,96	62,54	75,88	73,45	65,44	69,23
Succulent feeds	694,70	632,39	582,90	447,41	298,64	243,52	293,72	292,84	266,71	256,43
Coarse feeds	195,63	213,71	239,55	229,28	198,21	221,45	264,77	267,13	245,40	223,47
Other feeds	1 276,17	1 391,44	1 563,95	1 501,47	1 299,51	1 452,60	1 748,76	1 742,68	1 586,15	1 524,40
Bulls										
Concentrated feeds	2,11	2,71	3,38	3,58	3,50	4,17	4,55	4,43	3,96	4,06
Succulent feeds	33,29	37,39	40,28	36,02	28,79	27,09	34,00	32,34	30,04	27,86

Kind of feeds	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Coarse feeds	10,58	14,12	18,17	19,87	20,04	24,64	29,07	27,76	25,30	24,43
Other feeds	52,40	70,79	92,44	102,43	104,45	129,80	153,33	146,72	133,88	129,23
Other cattle										
Concentrated feeds	312,34	377,61	381,49	382,76	383,64	335,78	333,94	310,48	311,59	333,72
Succulent feeds	3 180,99	3 332,76	2 876,49	2 393,80	1 913,60	1 271,94	1 263,73	1 214,66	1 249,55	1 216,63
Coarse feeds	884,82	1 113,31	1 166,86	1 211,31	1 254,82	1 136,47	1 112,92	1 078,93	1 116,42	1 028,95
Other feeds	5 934,33	7 492,64	7 899,34	8 245,91	8 575,82	7 798,87	7 695,80	7 366,51	7 552,44	7 348,70

Kind of feeds	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle at agricultural enterprises										
Cows										
Concentrated feeds	864.52	867.98	1 029.48	1 053.38	1 099.64	1 166.23	1 131.74	1 160.79	1 440.06	1 380.88
Succulent feeds	6 573.00	6 551.51	6 592.05	6 539.08	6 151.57	5 871.27	6 000.80	6 000.24	3 063.59	3 170.00
Coarse feeds	1 169.11	1 137.41	1 202.20	1 240.07	1 334.54	1 305.37	1 295.20	1 234.71	1 260.04	1 222.29
Other feeds	1 557.93	1 556.65	1 350.37	1 151.75	1 023.52	934.72	792.46	760.05	462.92	479.23
Heifers 2 years and older										
Concentrated feeds	87.65	80.05	87.04	85.40	83.96	80.77	72.23	65.95	87.37	77.76
Succulent feeds	715.12	683.05	651.53	650.02	582.58	521.77	500.85	445.83	233.92	212.26
Coarse feeds	148.75	136.49	133.12	132.16	137.13	126.90	112.62	105.42	115.85	101.04
Other feeds	188.65	181.44	170.90	164.64	135.34	116.49	85.36	75.27	50.88	49.99
Heifers from 1 to 2 years										
Concentrated feeds	50.12	49.78	58.86	60.27	62.64	64.16	91.30	124.75	176.31	163.01
Succulent feeds	389.66	404.01	423.05	439.13	411.21	394.22	607.77	800.53	444.25	416.69
Coarse feeds	78.14	76.99	82.44	85.32	93.28	92.59	131.10	183.98	214.63	194.72
Other feeds	108.89	109.99	112.00	114.02	98.84	94.19	112.77	147.85	106.78	111.09
Bulls										
Concentrated feeds	1.96	1.82	1.97	1.64	1.48	1.40	1.22	1.09	1.26	1.15
Succulent feeds	12.00	11.22	10.19	8.23	6.74	5.75	5.44	4.71	2.16	2.13
Coarse feeds	2.29	2.07	2.01	1.69	1.59	1.40	1.22	0.98	0.92	0.85
Other feeds	5.33	5.08	3.96	3.01	2.48	2.03	1.39	1.08	0.60	0.61
Beef cows										

Kind of feeds	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Concentrated feeds	29.94	26.49	30.09	29.39	25.43	22.26	20.28	18.98	27.48	27.68
Succulent feeds	203.30	196.29	183.63	174.24	147.82	117.67	115.58	106.40	57.74	60.62
Coarse feeds	61.16	56.41	54.71	54.53	52.80	44.97	39.81	36.14	42.86	43.47
Other feeds	101.82	103.18	103.29	94.35	74.38	59.25	35.63	31.28	22.41	24.03
Cows on fattening										
Concentrated feeds	27.87	26.23	28.49	27.67	27.18	27.00	25.81	25.02	34.68	32.85
Succulent feeds	262.74	260.12	249.62	246.32	220.87	205.40	212.61	200.23	109.29	105.23
Coarse feeds	56.47	53.09	51.72	50.74	52.46	50.15	47.45	47.11	54.00	50.19
Other feeds	65.86	64.70	61.13	58.29	47.64	42.97	33.43	30.89	21.95	23.31
Other cattle and beef cattle on fattening										
Concentrated feeds	119.52	111.91	123.45	120.00	114.86	113.62	109.57	105.25	146.69	140.39
Succulent feeds	916.29	904.63	870.53	854.35	751.93	692.40	720.65	674.42	369.28	359.73
Coarse feeds	215.05	202.81	199.50	196.24	199.42	190.53	181.77	177.88	205.37	193.36
Other feeds	296.60	293.80	284.41	268.16	214.06	191.69	146.01	133.18	94.91	101.12
Other cattle										
Concentrated feeds	249.06	216.80	248.52	247.47	238.71	236.65	217.40	173.58	177.58	182.08
Succulent feeds	1 946.84	1 760.38	1 815.35	1 818.27	1 580.83	1 464.83	1 478.90	1 140.45	448.82	475.27
Coarse feeds	368.88	314.70	328.09	329.87	331.77	318.94	288.56	237.99	203.87	201.79
Other feeds	553.06	457.93	451.91	452.68	348.62	328.91	248.69	182.92	108.06	116.21
Cattle at households										
Cows										
Concentrated feeds	757.44	755.92	738.49	719.93	684.27	654.26	632.50	617.02	613.07	567.52
Succulent feeds	6 456.72	6 116.02	6 027.58	6 168.97	5 961.30	5 826.52	5 738.38	5 521.97	5 141.76	4 862.82
Coarse feeds	5 879.95	5 691.47	5 587.96	5 604.26	5 377.77	5 208.09	5 090.19	4 922.85	4 704.99	4 410.63
Other feeds	25 884.35	25 069.55	24 628.22	24 709.96	23 727.20	22 987.92	22 469.68	21 747.94	20 796.12	19 485.84
Heifers 2 years and older										
Concentrated feeds	25.03	25.43	24.27	23.28	23.68	22.61	21.85	20.90	21.17	19.73
Succulent feeds	97.59	94.83	89.89	88.50	87.42	83.52	81.21	78.15	75.00	70.02
Coarse feeds	87.56	82.91	78.20	78.42	76.33	73.12	71.27	68.86	63.63	59.29
Other feeds	529.63	516.33	489.08	482.14	478.91	458.61	444.86	428.27	410.78	382.27
Heifers from 1 to 2 years										
Concentrated feeds	65.22	62.94	67.28	69.01	63.15	56.03	54.34	52.28	52.19	48.39
Succulent feeds	238.51	220.56	234.38	246.96	219.83	195.54	190.84	184.60	174.36	161.57

Kind of feeds	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coarse feeds	206.72	186.50	197.48	212.01	185.95	166.07	162.56	157.77	143.32	132.38
Other feeds	1 418.61	1 312.12	1 393.22	1 468.14	1 308.40	1 163.63	1 134.79	1 098.11	1 037.65	961.54
Bulls										
Concentrated feeds	3.65	3.34	3.36	3.16	2.62	2.25	2.13	2.06	1.89	1.62
Succulent feeds	24.89	21.52	21.88	21.56	18.06	15.82	15.34	14.62	12.61	11.05
Coarse feeds	21.94	19.47	19.73	19.09	15.97	13.91	13.36	12.80	11.31	9.78
Other feeds	115.99	102.78	104.04	100.62	84.12	73.18	70.29	67.35	59.59	51.60
Other cattle										
Concentrated feeds	301.79	308.60	364.12	399.75	365.79	311.21	321.15	323.70	322.36	300.45
Succulent feeds	1 083.87	1 059.99	1 243.43	1 401.23	1 243.56	1 059.15	1 101.00	1 115.72	1 051.81	981.79
Coarse feeds	913.65	873.20	1 019.82	1 171.74	1 028.14	880.11	916.03	931.85	844.94	784.84
Other feeds	6 563.92	6 433.42	7 540.49	8 504.75	7 578.44	6 463.74	6 706.11	6 798.84	6 408.92	5 969.81

Kind of feeds	2020	2021
Cattle at agricultural enterprises		
Cows		
Concentrated feeds	1 391.15	1 391.15
Succulent feeds	3 179.72	3 179.72
Coarse feeds	1 225.76	1 225.76
Other feeds	412.60	412.60
Heifers 2 years and older		
Concentrated feeds	68.92	62.33
Succulent feeds	185.68	176.51
Coarse feeds	93.33	87.52
Other feeds	36.40	37.79
Heifers from 1 to 2 years		
Concentrated feeds	152.43	147.75
Succulent feeds	386.45	390.20
Coarse feeds	191.13	191.53
Other feeds	84.06	96.63
Bulls		

Kind of feeds	2020	2021
Concentrated feeds	0.72	0.82
Succulent feeds	1.41	1.60
Coarse feeds	0.57	0.62
Other feeds	0.38	0.31
Beef cows		
Concentrated feeds	25.66	25.16
Succulent feeds	59.33	59.48
Coarse feeds	43.32	43.39
Other feeds	19.47	20.65
Cows on fattening		
Concentrated feeds	30.92	29.48
Succulent feeds	98.26	98.09
Coarse feeds	49.39	48.63
Other feeds	17.85	19.95
Other cattle and beef cattle on fattening		
Concentrated feeds	131.49	125.23
Succulent feeds	335.74	333.90
Coarse feeds	189.78	186.78
Other feeds	77.73	85.50
Other cattle		
Concentrated feeds	176.50	176.25
Succulent feeds	449.89	467.34
Coarse feeds	204.05	213.58
Other feeds	90.57	114.04
Cattle at households		
Cows		
Concentrated feeds	530.09	523.64
Succulent feeds	4 525.50	4 635.11
Coarse feeds	4 110.64	4 149.82
Other feeds	18 156.64	18 324.03
Heifers 2 years and older		
Concentrated feeds	19.18	17.29
Succulent feeds	67.65	60.46

Kind of feeds	2020	2021
Coarse feeds	57.00	50.66
Other feeds	369.15	330.46
Heifers from 1 to 2 years		
Concentrated feeds	46.26	41.75
Succulent feeds	153.33	136.99
Coarse feeds	124.84	110.72
Other feeds	912.84	816.57
Bulls		
Concentrated feeds	1.48	1.28
Succulent feeds	10.09	9.03
Coarse feeds	8.93	7.88
Other feeds	47.14	41.66
Other cattle		
Concentrated feeds	276.97	188.18
Succulent feeds	899.08	604.46
Coarse feeds	714.22	477.43
Other feeds	5 465.93	3 680.90

Table A3.2.3.7. Crude protein content in all kinds of cattle fodders, %

Sex-age groups	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agricultural enterprises										
Dairy cows	11,29	11,03	10,68	10,76	11,08	10,51	9,99	8,95	9,25	9,60
Heifers 2 years and older	8,60	8,36	8,08	8,31	8,56	8,19	7,83	7,12	7,34	7,57
Heifers from 1 to 2 years	8,74	8,53	8,29	8,51	8,76	8,40	8,04	7,33	7,56	7,78
Bulls	7,86	7,70	7,61	7,71	7,86	7,59	7,31	6,69	6,92	7,14
Beef cows	9,13	8,87	8,65	8,93	9,16	8,73	8,30	7,51	7,75	7,98
Cows on fattening	7,42	7,23	6,93	7,11	7,27	6,98	6,69	6,15	6,36	6,56
Other cattle and beef cattle fattening	7,96	7,78	7,54	7,72	7,90	7,62	7,34	6,76	6,95	7,14
Other cattle	8,74	8,56	8,36	8,57	8,77	8,47	8,16	7,50	7,68	7,88
Cattle at households										
Dairy cows	7,70	7,59	7,74	7,68	7,73	7,80	7,87	7,87	8,01	8,14
Heifers 2 years and older	6,56	6,45	6,46	6,36	6,45	6,61	6,76	6,96	7,09	7,22
Heifers from 1 to 2 years	6,62	6,52	6,54	6,42	6,52	6,64	6,76	6,96	7,11	7,26
Bulls	6,29	6,22	6,25	6,25	6,27	6,33	6,39	6,38	6,53	6,68
Other cattle	6,52	6,46	6,49	6,40	6,53	6,68	6,82	6,99	7,13	7,27

Sex-age groups	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agricultural enterprises										
Dairy cows	9,94	10,29	10,63	10,98	11,32	11,65	12,05	11,81	12,46	13,60
Heifers 2 years and older	7,80	8,03	8,26	8,49	8,71	8,94	9,28	9,13	9,37	10,11
Heifers from 1 to 2 years	8,00	8,23	8,45	8,67	8,90	9,13	9,41	9,31	9,56	10,34
Bulls	7,35	7,57	7,79	8,01	8,23	8,42	8,52	8,42	8,71	9,48
Beef cows	8,22	8,45	8,69	8,94	9,22	9,52	9,65	9,36	9,72	10,64
Cows on fattening	6,77	6,98	7,18	7,37	7,57	7,77	8,01	7,92	8,15	8,77
Other cattle and beef cattle fattening	7,33	7,52	7,70	7,89	8,09	8,29	8,50	8,40	8,59	9,24
Other cattle	8,09	8,29	8,48	8,67	8,85	9,03	9,28	9,21	9,41	10,14
Cattle at households										
Dairy cows	8,27	8,40	8,53	8,66	8,78	8,91	8,74	8,78	8,74	8,87
Heifers 2 years and older	7,34	7,47	7,60	7,72	7,85	7,97	7,99	7,92	7,87	8,05
Heifers from 1 to 2 years	7,41	7,56	7,70	7,85	8,00	8,15	8,18	8,16	8,15	8,29

Sex-age groups	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bulls	6,83	6,97	7,12	7,27	7,41	7,56	7,45	7,48	7,46	7,55
Other cattle	7,42	7,56	7,71	7,85	8,00	8,14	8,15	8,12	8,10	8,21

Sex-age groups	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle at agricultural enterprises										
Dairy cows	13.67	13.71	14.70	14.97	15.52	16.11	15.95	16.13	20.22	19.91
Heifers 2 years and older	9.83	9.69	10.17	10.11	10.48	10.78	10.66	10.74	13.84	13.77
Heifers from 1 to 2 years	10.04	9.90	10.36	10.33	10.78	11.05	10.88	11.02	14.21	14.14
Bulls	9.42	9.38	10.06	10.22	10.57	10.93	10.83	10.97	13.78	13.56
Beef cows	10.35	9.97	10.67	10.84	10.97	11.33	11.43	11.52	14.94	14.79
Cows on fattening	8.53	8.37	8.80	8.80	9.14	9.38	9.24	9.34	11.93	11.88
Other cattle and beef cattle fattening	8.98	8.80	9.23	9.23	9.57	9.81	9.69	9.78	12.45	12.39
Other cattle	9.81	9.72	10.12	10.10	10.59	10.82	10.61	10.77	13.79	13.75
Cattle at households										
Dairy cows	8.88	8.95	8.93	8.87	8.85	8.82	8.79	8.81	8.89	8.87
Heifers 2 years and older	8.08	8.17	8.20	8.17	8.22	8.21	8.20	8.19	8.29	8.28
Heifers from 1 to 2 years	8.30	8.35	8.35	8.30	8.34	8.32	8.32	8.31	8.41	8.41
Bulls	7.54	7.59	7.58	7.53	7.52	7.50	7.48	7.49	7.54	7.52
Other cattle	8.23	8.28	8.29	8.26	8.29	8.29	8.28	8.27	8.35	8.35

Sex-age groups	2020	2021
Cattle at agricultural enterprises		
Dairy cows	20.02	19.99
Heifers 2 years and older	13.84	13.64
Heifers from 1 to 2 years	14.21	14.02
Bulls	13.41	13.56
Beef cows	14.62	14.47
Cows on fattening	11.96	11.78
Other cattle and beef cattle fattening	12.46	12.28
Other cattle	13.86	13.67

Sex-age groups	2020	2021
Cattle at households		
Dairy cows	8.87	8.82
Heifers 2 years and older	8.29	8.29
Heifers from 1 to 2 years	8.44	8.47
Bulls	7.52	7.49
Other cattle	8.36	8.37

A3.2.4 Rice Cultivation

Table A3.2.4.1. Annual harvested area (ha) and the norm of organic fertilizers application for rice (t/ha)

Data category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Annual harvested area	27 700.0	22 900.0	24 300.0	23 400.0	22 400.0	22 000.0	23 000.0	22 500.0	20 700.0	21 900.0
Standard organic fertilizer application	1.88	1.47	1.05	0.62	0.53	0.45	0.37	0.13	0.23	0.25

Data category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Annual harvested area	25 200.0	18 800.0	18 900.0	22 400.0	21 300.0	21 400.0	21 600.0	21 100.0	19 800.0	24 500.0
Standard organic fertilizer application	0.07	0.38	0.17	0.03	0.07	NO	0.20	0.08	0.03	0.08

Data category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Annual harvested area	29 300.0	29 600.0	25 800.0	24 200.0	10 200.0	11 700.0	12 019.8	12 700.0	12 628.4	10 500.0
Standard organic fertilizer application	0.03	0.10	0.10	NO	NO	NO	NO	NO	NO	NO

Data category	2020	2021
Annual harvested area	11 200.00	10 100.00
Standard organic fertilizer application	NO	NO

A3.2.5 Agricultural Soils

Table A3.2.5.1. Amount of N that was applied to managed soils, kt of N

Data category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Annual amount of N in synthetic fertilizers	1 841.86	1 566.74	1 291.61	1 016.49	802.55	588.62	374.68	415.89	408.82	329.10
Annual amount of N in organic fertilizers	495.30	472.38	434.90	414.58	400.97	357.37	309.94	249.88	229.61	223.54
Annual amount of N in crop residues	2 944.22	2 810.22	2 721.28	2 803.32	2 290.32	2 214.33	1 848.30	1 934.75	1 705.61	1 430.83
Annual amount of N in mineral soils that is mineralized	NO	NO	NO	14.09	NO	59.00	59.12	257.79	138.52	155.85
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	373.31	355.33	346.36	342.84	333.87	301.40	270.92	234.02	221.26	211.19

Data category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Annual amount of N in synthetic fertilizers	224.17	319.10	313.86	272.88	365.93	377.24	467.23	578.47	736.12	635.13
Annual amount of N in organic fertilizers	201.66	193.87	201.92	191.08	172.32	165.98	166.44	159.01	148.42	150.35
Annual amount of N in crop residues	1 416.32	1 427.25	1 372.55	1 162.95	1 375.16	1 330.70	1 336.29	1 171.72	1 542.77	1 448.75
Annual amount of N in mineral soils that is mineralized	318.42	450.92	457.81	255.41	535.87	569.43	466.55	307.95	779.79	716.89
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	202.88	199.12	200.55	189.45	174.53	165.45	154.96	144.05	135.49	135.32

Data category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Annual amount of N in synthetic fertilizers	774.83	899.04	928.64	1 041.13	1 052.80	1 015.92	1 227.02	1 396.56	1 585.58	1 631.89
Annual amount of N in organic fertilizers	152.02	148.91	150.09	152.94	150.80	144.49	140.52	136.94	141.55	136.89
Annual amount of N in crop residues	1 442.25	1 784.98	1 690.03	1 993.10	2 013.05	1 918.80	2 093.00	1 968.95	2 205.44	2 237.92
Annual amount of N in mineral soils that is mineralized	532.03	950.62	782.83	1 114.50	1 164.18	1 066.70	1 184.83	979.20	1 172.93	1 256.65
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	129.86	126.42	129.71	129.64	125.86	120.95	118.03	116.52	125.58	119.03

Data category	2020	2021
Annual amount of N in synthetic fertilizers	1 946.39	1 999.17
Annual amount of N in organic fertilizers	131.42	125.64
Annual amount of N in crop residues	1 986.79	2 392.32

Data category	2020	2021
Annual amount of N in mineral soils that is mineralized	716.06	1 267.49
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	113.66	107.97

Table A3.2.5.2. Amount of applied inorganic nitrogen fertilizers by zones and regions, kt of N

Nitrogen fertilizers applied	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Polissia	423.11	360.25	297.39	234.53	184.30	134.07	83.84	82.61	90.75	66.47
Wooded Steppe	745.86	654.01	562.16	470.31	371.84	273.37	174.90	181.71	172.56	160.52
Steppe	672.89	552.48	432.06	311.65	246.41	181.18	115.94	151.57	145.51	102.11
of them for rice	4.43	3.66	3.89	3.74	3.58	3.52	3.68	3.60	3.31	3.50

Nitrogen fertilizers applied	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Polissia	45.40	58.35	41.00	44.47	64.32	62.73	73.04	74.60	107.32	92.22
Wooded Steppe	107.51	149.92	137.20	119.11	162.72	158.21	218.39	276.87	373.00	308.36
Steppe	71.26	110.83	135.67	109.29	138.89	156.30	175.80	227.00	255.80	234.55
of them for rice	4.03	3.01	3.02	3.58	3.41	3.42	3.46	3.38	3.17	3.95

Nitrogen fertilizers applied	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Polissia	102.63	125.87	142.04	180.60	183.15	179.64	215.25	242.43	296.09	285.24
Wooded Steppe	390.04	453.64	480.42	526.04	519.13	516.68	602.15	663.84	719.94	727.57
Steppe	282.16	319.53	306.18	334.49	350.52	319.60	409.62	490.29	569.54	619.08
of them for rice	3.99	4.65	3.58	3.73	1.70	2.04	2.04	2.20	2.72	1.88

Nitrogen fertilizers applied	2020	2021
Polissia	351.93	394.58
Wooded Steppe	845.26	839.02
Steppe	749.20	765.57
of them for rice	1.98	1.80

Table A3.2.5.3. Regression coefficients depending on the crop yields, as well as the proportion of nitrogen in side-products, stubble and roots

Agricultural crop	Productivity, kg/ha	Side-products		Stubble		Roots		Nitrogen content in side-products and stubble, rel. u	Nitrogen content in roots, rel. u
		Regression co-efficient *a*	Regression coefficient *b*	Regression coefficient *c*	Regression coefficient *d*	Regression coefficient *x*	Regression coefficient *y*		
Winter wheat	10-25 26-40	-	-	0.4 0.1	2.6 8.9	0.9 0.7	5.8 10.2	0.0045	0.0075
Spring wheat	10-20 21-30	-	-	0.4 0.2	1.8 5.4	0.8 0.8	6.5 6.0	0.0065	0.0080
Winter rye	10-25 26-40	-	-	0.3 0.2	3.2 6.3	0.6 0.6	8.9 13.9	0.0045	0.0075
Spring rye	10-25 26-40	-	-	0.3 0.2	3.2 6.3	0.6 0.6	8.9 13.9	0.0056	0.0075
Barley and cereals mix	10-20 21-35	-	-	0.4 0.09	1.8 7.6	0.8 0.4	6.5 13.4	0.0050	0.0120
Oats	10-20 21-35	-	-	0.3 0.15	3.2 6.1	1.0 0.4	2.0 16.0	0.0060	0.0075
Millet	5-20 21-30	-	-	0.2 0.3	5.0 3.3	0.8 0.56	7.0 11.2	0.0050	0.0075
Buckwheat	5-15 16-30	-	-	0.25 0.2	4.3 5.2	1.1 0.54	5.3 14.1	0.0080	0.0085
Corn for grain	10-35	1.2	17.5	0.23	3.5	0.8	5.8	0.0075	0.0100
Rice	10-20 21-35	-	-	0.4 0.09	1.8 7.6	0.8 0.4	6.5 13.4	0.0067	0.0120
Sorghum	5-20 21-30	-	-	0.2 0.3	5.0 3.3	0.8 0.56	7.0 11.2	0.0080	0.006
Peas	5-20 21-30	-	-	0.14 0.2	3.5 1.7	0.66 0.37	7.5 12.9	0.0125	0.0170
Vetch	5-20 21-30	-	-	0.14 0.2	3.5 1.7	0.66 0.37	7.5 12.9	0.0125	0.017
Perennial herbs for hay, seed, and green fodder, hay meadows and cultivated pastures	10-40 30-60	-	-	0.2 0.1	6.0 10.0	0.8 1.0	11.0 15.0	0.0190	0.021
Soybean	5-20 21-30	1.3 1.2	4.5 3	0.14 0.2	3.5 1.7	0.66 0.37	7.5 12.9	0.0120	0.008
Broad beans for grain	5-20 21-30	-	-	0.14 0.2	3.5 1.7	0.66 0.37	7.5 12.9	0.0125	0.017
Sugar beet (factory), sugar beet for seeds and animal feed	100-200 201-400	-	-	0.02 0.003	0.8 2.3	0.07 0.06	3.5 5.4	0.0140	0.012
Potato	50-200 201-400	0.12 0.1	2 3.9	0.04 0.03	1.0 4.1	0.08 0.06	4.0 8.6	0.0180	0.012
Vegetables, seed bearers of annual vegetable crops, seed bearers of biennial vegetable crops	50-200 250-400	0.12 0.12	0.5 0	0.02 0.006	1.5 3.6	0.06 0.04	5.0 6.0	0.0035	0.010

Agricultural crop	Productivity, kg/ha	Side-products		Stubble		Roots		Nitrogen content in side-products and stubble, rel. u	Nitrogen content in roots, rel. u
		Regression co-efficient *a*	Regression coefficient *b*	Regression coefficient *c*	Regression coefficient *d*	Regression coefficient *x*	Regression coefficient *y*		
Fodder root crops, fodder root crops for seeds	50-200 200-400	-	-	0.01 0.003	1.0 2.4	0.05 0.05	5.5 5.2	0.0130	0.010
Sunflower	8-30	1.8	5.3	0.4	3.1	1	6.6	0.0075	0.010
Fiber flax, crown flax	3-10	-	-	-	-	1.3	9.4	0.0050	0.008
Winter and spring rapeseed	10-40	-	-	0.13	6	0.7	7.5	0.0070	0.012
Annual grasses for hay, green fodder, and seeds	10-40	-	-	0.13	6	0.7	7.5	0.0110	0.012
Corn for silage	100-200 201-350	-	-	0.03 0.02	3.6 5	0.12 0.08	8.7 16.2	0.008 0.008	0.012 0.012
Beans and lupine	5-20 22-30	-	-	0.14 0.2	3.5 1.7	0.66 0.37	7.5 12.9	0.01 0.01	0.01 0.01
Chick-pea, lathyrus, mung bean	5-20 22-30	-	-	0.14 0.2	3.5 1.7	0.66 0.37	7.5 12.9	0.012 0.012	0.017 0.017
Hemp	3-10	-	-			2.2	9.1	0.0025	0.005
Tobacco and wild tobacco	50-200	-	-	0.04	1.0	0.08	4.0	0.0164	0.012
Mustard and false flax	10-40	-	-	0.13	6	0.7	7.5	0.01	0.012
Food and feed melons, melon seed bearers	50-200	0.12	0.5	0.02	1.5	0.06	5.0	0.0025	0.01
Silage crops without corn	100-200	-	-	0.04	4	0.09	7	0.01	0.011
Coriander	50-200	-	-	0.02	1.5	0.06	5.0	0.02	0.01
Castor-oil plant	8-30	-	-	0.4	3.1	1	6.6	0.007	0.01

Table A3.2.5.4. Annual area of managed/drained organic soils, ha

Data category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Area of managed/drained organic soils	476 700.0	481 400.0	485 000.0	486 300.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0

Data category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Area of managed/drained organic soils	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0	488 000.0

Data category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Area of managed/drained organic soils	488 000.0	488 000.0	488 000.0	478 350.0	478 350.0	478 350.0	478 350.0	478 400.0	474 500.0	472 850.0

Data category	2020	2021
Area of managed/drained organic soils	471 602.0	471 602.0

A3.2.6 Liming

Table A3.2.6.1. Annual amount of liming materials applied, kt

Activity data	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
The amount of lime fertilizers in full weight	6 930.70	3 613.00	3 613.00	3 613.00	3 613.00	3 613.00	800.00	204.30	208.00	188.85
The amount of lime fertilizers in weight of active matter	5 891.10	3 071.05	3 071.05	3 071.05	3 071.05	3 071.05	680.00	173.66	176.80	160.52

Activity data	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
The amount of lime fertilizers in full weight	169.70	191.10	143.80	132.00	222.80	243.10	283.40	300.40	334.10	406.10
The amount of lime fertilizers in weight of active matter	144.25	162.44	122.23	112.20	189.38	206.64	240.89	255.34	283.99	345.19

Activity data	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
The amount of lime fertilizers in full weight	340.80	340.00	432.40	487.30	417.80	454.10	374.59	450.80	437.80	378.00
The amount of lime fertilizers in weight of active matter	289.68	289.00	367.54	414.21	355.13	385.99	318.40	383.18	372.13	321.30

Activity data	2020	2021
The amount of lime fertilizers in full weight	351.20	471.20
The amount of lime fertilizers in weight of active matter	298.52	400.52

A3.2.7 Urea Application

Table A3.2.7.1. Amount of urea used as fertilizer, kt

Urea applied	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cropland	368.37	313.35	258.32	203.30	160.51	117.72	74.94	83.18	81.76	65.82

Urea applied	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cropland	112.09	159.55	159.43	260.59	48.86	188.62	233.62	289.24	484.34	238.68

Urea applied	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cropland	456.45	533.89	496.81	459.73	422.65	385.57	348.49	311.41	274.33	284.79

Urea applied	2020	2021
Cropland	321.15	321.28

A3.2.8 Emission factors

Table A3.2.8.1. Methane emission factors from enteric fermentation of cattle, kg of CH_4 head^{-1}

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agrienterprises										
Cows	86.3	84.3	80.3	79.5	79.1	78.0	76.4	73.3	75.7	76.3
Heifers 2 years and older	63.8	64.3	64.8	64.8	65.2	65.3	65.4	65.3	65.2	65.2
Heifers from 1 to 2 years	52.5	52.6	53.0	52.9	53.1	53.2	53.3	53.2	53.2	53.2
Bulls	69.4	69.8	70.4	70.3	70.5	70.7	70.9	70.8	70.8	70.8
Beef cows	49.1	49.8	50.3	50.3	50.7	50.8	50.8	50.6	50.6	50.6
Cows on fattening	92.0	93.1	94.1	94.2	95.0	95.1	95.2	94.7	94.7	94.7
Cattle on fattening (excluding cows)	43.1	43.6	44.0	44.1	44.4	44.5	44.5	44.3	44.3	44.3
Other cattle	38.1	38.2	38.5	38.4	38.5	38.6	38.6	38.6	38.6	38.5
Households										
Cows	90.3	90.2	89.9	90.2	90.1	90.6	90.5	91.1	91.7	91.9
Heifers 2 years and older	63.6	63.5	63.5	63.4	63.4	63.4	63.5	63.7	63.7	63.6
Heifers from 1 to 2 years	55.1	54.9	55.0	54.9	54.8	54.9	54.9	55.1	55.0	54.8
Bulls	69.3	69.3	69.3	69.3	69.3	69.3	69.3	69.3	69.2	69.1
Other cattle	44.2	44.1	44.1	44.1	44.0	44.1	44.1	44.3	44.1	44.0

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agrienterprises										
Cows	75.2	79.7	80.9	79.4	83.5	87.9	89.1	89.6	91.6	96.9
Heifers 2 years and older	65.2	65.2	65.2	65.2	65.1	65.1	64.9	64.9	64.5	64.9
Heifers from 1 to 2 years	53.2	53.1	53.1	53.1	53.1	53.1	52.9	52.9	52.6	52.8
Bulls	70.8	70.7	70.7	70.6	70.6	70.5	70.3	70.5	70.1	70.4
Beef cows	50.6	50.6	50.6	50.6	50.6	50.5	50.3	50.4	49.9	50.2
Cows on fattening	94.6	94.5	94.5	94.4	94.3	94.3	93.9	94.1	93.4	94.1
Cattle on fattening (excluding cows)	44.3	44.2	44.2	44.2	44.2	44.2	44.0	44.1	43.7	44.0
Other cattle	38.5	38.5	38.5	38.5	38.4	38.4	38.3	38.3	38.0	38.2
Households										
Cows	92.7	93.7	94.7	94.7	96.5	98.5	100.1	100.0	100.9	102.7
Heifers 2 years and older	63.5	63.5	63.4	63.4	63.3	63.2	63.2	63.3	63.3	63.2
Heifers from 1 to 2 years	54.6	54.5	54.3	54.1	54.0	53.8	53.8	53.8	53.9	53.7

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bulls	69.0	68.9	68.9	68.8	68.7	68.6	68.6	68.6	68.6	68.6
Other cattle	43.8	43.7	43.5	43.4	43.3	43.1	43.1	43.1	43.2	43.1

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agrienterprises										
Cows	97.7	96.2	101.5	103.3	106.6	109.6	112.8	115.9	116.9	117.9
Heifers 2 years and older	64.8	64.7	64.7	64.7	65.3	65.4	65.4	65.6	67.2	66.9
Heifers from 1 to 2 years	52.8	52.7	52.7	52.7	53.0	53.0	52.9	53.0	54.2	54.0
Bulls	70.4	70.3	70.5	70.7	71.1	71.1	71.3	71.1	72.1	72.0
Beef cows	50.3	50.0	49.9	50.2	50.8	51.0	52.0	52.1	54.2	54.0
Cows on fattening	94.0	93.8	93.8	93.9	94.9	95.1	95.3	95.7	98.8	98.2
Cattle on fattening (excluding cows)	44.0	43.9	43.9	44.0	44.4	44.5	44.8	44.9	46.2	46.0
Other cattle	38.2	38.1	38.1	38.1	38.3	38.3	38.2	38.3	39.1	39.0
Households										
Cows	102.8	104.0	104.6	105.4	106.2	106.7	106.6	107.1	108.3	109.1
Heifers 2 years and older	63.2	63.1	63.1	63.1	63.1	63.1	63.1	63.1	63.0	63.0
Heifers from 1 to 2 years	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.6	53.6
Bulls	68.6	68.6	68.6	68.6	68.6	68.6	68.6	68.6	68.6	68.6
Other cattle	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	42.9	42.9

Sex-age group	2020	2021
Agrienterprises		
Cows	121.7	123.0
Heifers 2 years and older	67.4	67.4
Heifers from 1 to 2 years	54.3	54.3
Bulls	72.3	72.3
Beef cows	54.7	54.5
Cows on fattening	99.3	99.0
Cattle on fattening (excluding cows)	46.5	46.4
Other cattle	39.2	39.2
Households		

Sex-age group	2020	2021
Cows	109.5	111.0
Heifers 2 years and older	63.0	63.0
Heifers from 1 to 2 years	53.6	53.6
Bulls	68.6	68.6
Other cattle	42.9	42.9

Table A3.2.8.2. Methane emission factors from enteric fermentation of sheep, kg of CH_4 head^{-1}

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Ewes and young ewes 1 year and older	8.88	8.84	8.83	8.84	8.85	8.85	8.87	8.97	9.02	9.08
Breeding rams	13.30	13.28	13.27	13.27	13.26	13.20	13.19	13.22	13.20	13.22
Wethers (castrated rams)	7.55	7.54	7.53	7.53	7.52	7.49	7.48	7.50	7.49	7.50
Feeding livestock	6.24	6.23	6.22	6.22	6.21	6.19	6.18	6.20	6.19	6.20
Lambs to 4 months and Repair Lambs 4-12 months	5.63	5.62	5.61	5.61	5.60	5.58	5.58	5.59	5.58	5.59
Average weighted emission factor	*7.41*	*7.39*	*7.42*	*7.46*	*7.52*	*7.65*	*7.81*	*7.99*	*8.10*	*8.14*

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ewes and young ewes 1 year and older	9.21	9.31	9.34	9.21	9.76	9.45	9.54	9.62	9.51	9.24
Breeding rams	13.09	13.12	13.13	12.82	12.85	12.87	12.89	12.91	12.89	12.91
Wethers (castrated rams)	7.50	7.53	7.54	7.54	7.55	7.57	7.58	7.58	7.57	7.58
Feeding livestock	6.20	6.22	6.23	6.23	6.24	6.25	6.26	6.26	6.25	6.26
Lambs to 4 months and Repair Lambs 4-12 months	5.59	5.61	5.62	5.62	5.63	5.64	5.65	5.65	5.64	5.65
Average weighted emission factor	*8.17*	*8.21*	*8.18*	*8.11*	*8.58*	*8.51*	*8.67*	*8.77*	*8.74*	*8.54*

Sex-age group	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ewes and young ewes 1 year and older	9.52	10.06	10.02	10.00	9.90	9.86	9.75	9.82	9.89	9.79
Breeding rams	12.90	12.97	12.96	12.94	12.94	12.93	12.92	12.92	12.91	12.90
Wethers (castrated rams)	7.55	7.55	7.54	7.53	7.52	7.52	7.51	7.50	7.49	7.49
Feeding livestock	6.24	6.24	6.23	6.22	6.22	6.21	6.21	6.20	6.19	6.19
Lambs to 4 months and Repair Lambs 4-12 months	5.63	5.63	5.62	5.61	5.61	5.60	5.60	5.59	5.59	5.58
Average weighted emission factor	*8.71*	*9.01*	*8.89*	*8.86*	*8.78*	*8.74*	*8.65*	*8.69*	*8.73*	*8.63*

Sex-age group	2020	2021
Ewes and young ewes 1 year and older	9.84	9.92
Breeding rams	12.92	12.94
Wethers (castrated rams)	7.50	7.53
Feeding livestock	6.20	6.22
Lambs to 4 months and Repair Lambs 4-12 months	5.59	5.61
Average weighted emission factor	*8.67*	*8.76*

Table A3.2.8.3. Methane emission factors from enteric fermentation and manure management, kg of CH_4 head^{-1}

Animal species	Enteric fermentation	Manure management
Swine	1.5	–
Fur-bearing animals	0.25	0.68
Rabbits	0.7	0.08
Buffaloes	55.0	5.00
Goats	5.0	0.13
Camels	46.0	1.58
Horses	18.0	1.56
Asses and mules	10.0	0.76

Table A3.2.8.4. Methane emission factors from manure management of cattle, swine, sheep and poultry, kg of CH_4 head^{-1}

Animal species/groups	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agrienterprises										
Cows	6.36	6.27	5.43	5.21	4.78	4.27	4.02	3.25	3.04	3.06
Heifers 2 years and older	5.15	5.24	4.77	4.63	4.29	3.90	3.75	3.15	2.86	2.86
Heifers from 1 to 2 years	2.87	2.89	2.63	2.55	2.35	2.13	2.05	1.73	1.57	1.57
Bulls	3.42	3.47	3.19	3.08	2.84	2.59	2.51	2.11	1.91	1.91
Beef cows	2.79	2.88	2.63	2.56	2.39	2.17	2.08	1.74	1.58	1.58
Cows on fattening	5.06	5.18	4.75	4.62	4.31	3.91	3.76	3.14	2.84	2.84
Cattle on fattening (excluding cows)	2.35	2.41	2.21	2.15	2.00	1.82	1.75	1.46	1.32	1.32
Other cattle	2.08	2.10	1.91	1.85	1.70	1.55	1.49	1.25	1.14	1.13
Main sows	4.55	4.34	3.97	3.58	3.23	6.66	6.78	7.30	7.30	7.30
Sows tested	4.08	3.90	3.56	3.22	2.90	5.98	6.08	6.55	6.55	6.55
Repair swine 4 months and older	2.95	2.82	2.58	2.33	2.10	4.33	4.40	4.74	4.74	4.74
Piglets up to 2 months	0.33	0.31	0.28	0.26	0.23	0.48	0.49	0.52	0.52	0.52
Piglets 2 to 4 months	1.09	1.04	0.95	0.86	0.78	1.60	1.63	1.76	1.76	1.76
Fattening swine	3.17	3.03	2.77	2.50	2.26	4.65	4.73	5.09	5.09	5.09
Boars	5.30	5.06	4.62	4.17	3.77	7.77	7.90	8.51	8.51	8.51
Hens and roosters	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Geese	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Ducks	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Turkeys	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Other poultry	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Households										
Cows	3.11	3.10	3.10	3.10	3.10	3.12	3.12	3.13	3.14	3.14
Heifers 2 years and older	2.19	2.18	2.19	2.18	2.17	2.18	2.19	2.20	2.20	2.19
Heifers from 1 to 2 years	1.40	1.39	1.39	1.39	1.38	1.39	1.39	1.40	1.39	1.38
Bulls	1.63	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.61
Other cattle	1.12	1.11	1.12	1.11	1.11	1.11	1.11	1.12	1.12	1.11
Main sows	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Repair swine 4 months and older	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Piglets up to 2 months	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Piglets 2 to 4 months	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Fattening swine	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70

Animal species/groups	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Boars	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Hens and roosters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Geese	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Ducks	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Turkeys	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Other poultry	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
All categories of farms										
Ewes and gimmers 1 year and older	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.23
Rams	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Wethers	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Fattening livestock	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Lambs up to 4 months and 4-12 months repair young sheep	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Animal species/groups	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agrienterprises										
Cows	2.70	2.87	2.91	2.85	3.00	3.15	3.53	3.55	3.78	4.05
Heifers 2 years and older	2.57	2.57	2.56	2.56	2.56	2.56	2.81	2.82	2.91	2.96
Heifers from 1 to 2 years	1.41	1.41	1.40	1.40	1.40	1.40	1.54	1.54	1.59	1.62
Bulls	1.71	1.71	1.71	1.71	1.70	1.70	1.87	1.88	1.94	1.97
Beef cows	1.42	1.42	1.42	1.42	1.42	1.41	1.55	1.56	1.60	1.62
Cows on fattening	2.55	2.54	2.54	2.54	2.54	2.53	2.78	2.79	2.88	2.94
Cattle on fattening (excluding cows)	1.19	1.18	1.18	1.18	1.18	1.18	1.29	1.30	1.34	1.37
Other cattle	1.02	1.02	1.01	1.01	1.01	1.01	1.11	1.11	1.15	1.17
Main sows	7.49	7.56	7.86	8.01	7.94	9.44	9.06	10.26	11.76	12.13
Sows tested	6.72	6.79	7.06	7.19	7.13	8.47	8.14	9.21	10.56	10.89
Repair swine 4 months and older	4.87	4.91	5.11	5.21	5.16	6.13	5.89	6.67	7.64	7.89
Piglets up to 2 months	0.54	0.54	0.56	0.57	0.57	0.68	0.65	0.74	0.84	0.87
Piglets 2 to 4 months	1.80	1.82	1.89	1.93	1.91	2.27	2.18	2.47	2.83	2.92
Fattening swine	5.22	5.28	5.48	5.59	5.54	6.58	6.32	7.16	8.20	8.46
Boars	8.73	8.81	9.16	9.34	9.25	11.00	10.56	11.96	13.71	14.14
Hens and roosters	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Geese	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Ducks	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09

Animal species/groups	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Turkeys	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Other poultry	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Households										
Cows	3.17	3.19	3.22	3.21	3.26	3.32	3.38	3.37	3.41	3.46
Heifers 2 years and older	2.19	2.18	2.18	2.17	2.17	2.16	2.16	2.17	2.17	2.16
Heifers from 1 to 2 years	1.37	1.36	1.36	1.35	1.34	1.33	1.33	1.33	1.33	1.33
Bulls	1.61	1.60	1.60	1.59	1.59	1.58	1.58	1.58	1.58	1.58
Other cattle	1.10	1.09	1.09	1.08	1.07	1.06	1.06	1.06	1.07	1.06
Main sows	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Repair swine 4 months and older	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Piglets up to 2 months	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Piglets 2 to 4 months	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Fattening swine	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Boars	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Hens and roosters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Geese	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Ducks	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Turkeys	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Other poultry	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
All categories of farms										
Ewes and gimmers 1 year and older	0.23	0.23	0.23	0.23	0.25	0.24	0.24	0.24	0.24	0.23
Rams	0.33	0.33	0.33	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Wethers	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Fattening livestock	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Lambs up to 4 months and 4-12 months repair young sheep	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.20	0.21

Animal species/groups	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Agrienterprises										
Cows	4.14	3.99	4.25	4.40	4.60	4.77	4.97	5.02	5.12	5.20
Heifers 2 years and older	3.00	2.93	2.95	2.99	3.06	3.09	3.13	3.10	3.28	3.28
Heifers from 1 to 2 years	1.64	1.60	1.61	1.63	1.66	1.68	1.69	1.67	1.76	1.76
Bulls	2.00	1.95	1.98	2.02	2.07	2.08	2.12	2.07	2.16	2.17
Beef cows	1.65	1.60	1.61	1.64	1.70	1.73	1.82	1.80	1.97	1.97

Animal species/groups	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cows on fattening	2.98	2.91	2.92	2.96	3.06	3.09	3.14	3.12	3.34	3.33
Cattle on fattening (excluding cows)	1.38	1.35	1.36	1.38	1.42	1.44	1.47	1.46	1.56	1.55
Other cattle	1.18	1.15	1.16	1.17	1.20	1.21	1.21	1.20	1.27	1.27
Main sows	12.59	13.04	13.56	12.34	10.92	10.08	9.16	9.96	9.23	8.41
Sows tested	11.30	11.70	12.17	11.07	9.80	9.05	8.22	8.95	8.29	7.55
Repair swine 4 months and older	8.18	8.47	8.81	8.02	7.10	6.55	5.95	6.48	6.00	5.47
Piglets up to 2 months	0.90	0.93	0.97	0.88	0.78	0.72	0.66	0.71	0.66	0.60
Piglets 2 to 4 months	3.03	3.14	3.26	2.97	2.63	2.43	2.20	2.40	2.22	2.02
Fattening swine	8.78	9.09	9.46	8.60	7.62	7.03	6.39	6.95	6.44	5.87
Boars	14.67	15.19	15.80	14.38	12.73	11.75	10.67	11.61	10.76	9.80
Hens and roosters	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Geese	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Ducks	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Turkeys	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Other poultry	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Households										
Cows	3.47	3.50	3.52	3.55	3.58	3.60	3.59	3.61	3.65	3.68
Heifers 2 years and older	2.16	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Heifers from 1 to 2 years	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Bulls	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Other cattle	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.05	1.05
Main sows	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Repair swine 4 months and older	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Piglets up to 2 months	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Piglets 2 to 4 months	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Fattening swine	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Boars	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Hens and roosters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Geese	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Ducks	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Turkeys	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Other poultry	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
All categories of farms										

Animal species/groups	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ewes and gimmers 1 year and older	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Rams	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.32	0.32
Wethers	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Fattening livestock	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Lambs up to 4 months and 4-12 months repair young sheep	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Animal species/groups	2020	2021
Agrienterprises		
Cows	5.42	5.52
Heifers 2 years and older	3.35	3.37
Heifers from 1 to 2 years	1.80	1.81
Bulls	2.21	2.22
Beef cows	2.03	2.03
Cows on fattening	3.42	3.43
Cattle on fattening (excluding cows)	1.60	1.60
Other cattle	1.29	1.30
Main sows	8.40	8.74
Sows tested	7.54	7.84
Repair swine 4 months and older	5.46	5.68
Piglets up to 2 months	0.60	0.63
Piglets 2 to 4 months	2.02	2.10
Fattening swine	5.86	6.09
Boars	9.79	10.18
Hens and roosters	0.05	0.05
Geese	0.12	0.12
Ducks	0.09	0.09
Turkeys	0.17	0.17
Other poultry	0.13	0.13
Households		
Cows	3.69	3.74
Heifers 2 years and older	2.15	2.14
Heifers from 1 to 2 years	1.32	1.32
Bulls	1.58	1.58

Animal species/groups	2020	2021
Other cattle	1.05	1.05
Main sows	2.44	2.44
Repair swine 4 months and older	1.58	1.58
Piglets up to 2 months	0.17	0.17
Piglets 2 to 4 months	0.59	0.59
Fattening swine	1.70	1.70
Boars	2.84	2.84
Hens and roosters	0.04	0.04
Geese	0.10	0.10
Ducks	0.07	0.07
Turkeys	0.14	0.14
Other poultry	0.11	0.11
All categories of farms		
Ewes and gimmers 1 year and older	0.25	0.25
Rams	0.32	0.33
Wethers	0.19	0.19
Fattening livestock	0.21	0.21
Lambs up to 4 months and 4-12 months repair young sheep	0.20	0.20

Table A3.2.8.5. Nitrous oxide emission factors from manure management systems, kg of N_2O-N kg^{-1} of N

Manure management system	Emission factor
Uncovered anaerobic lagoon	0
Solid storage	0.005
Composting	0.006
Liquid slurry	0.005
Aerobic treatment	0.01
Poultry manure without litter	0.001
Other systems	0.002

Table A3.2.8.6. Adjusted daily methane emission factor from rice cultivation, kg of CH_4 ha^{-1}

Category 3.C Rice Cultivation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Adjusted daily emission factor	2.60	2.58	2.55	2.51	2.51	2.50	2.50	2.48	2.49	2.49

Category 3.C Rice Cultivation	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Adjusted daily emission factor	2.48	2.50	2.48	2.47	2.48	2.47	2.48	2.48	2.47	2.48

Category 3.C Rice Cultivation	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Adjusted daily emission factor	2.47	2.48	2.48	2.47	2.47	2.47	2.47	2.47	2.47	2.47

Category 3.C Rice Cultivation	2020	2021
Adjusted daily emission factor	2.47	2.47

Table A3.2.8.7. Coefficients for calculation direct and indirect nitrous oxide emissions from agricultural soils

Coefficient name	Units	Values
EF for N additions from mineral fertilizers, organic amendments and crop residues, and N mineralized from mineral soil as a result of loss of soil carbon	[kg N_2O–N (kg N)$^{-1}$]	0.01
EF for N additions from mineral fertilizers, organic amendments and crop residues, and N mineralized from mineral soil as a result of loss of soil carbon on rice fields	[kg N_2O–N (kg N)$^{-1}$]	0.003
EF for temperate organic crop and grassland soils	[kg N_2O–N ha^{-1}]	8.0
EF for cattle, poultry and swine	[kg N_2O–N (kg N)$^{-1}$]	0.02
EF for sheep and other animals	[kg N_2O–N (kg N)$^{-1}$]	0.01
$Frac_{GASF}$ (fraction of synthetic fertilizer N that volatilizes as NH_3 and NO_X)	(kg NH_3–N + NOx–N)×(kg of N applied)$^{-1}$	0.145
$Frac_{GASM}$ (fraction of applied organic N fertilizer materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH_3 and NO_X)	(kg NH_3–N + NOx–N)×(kg of N applied or deposited)$^{-1}$	0.2
$Frac_{LEACH-(H)}$ (fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff)	kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.3

A3.2.9 Emissions

Table A3.2.9.1. Methane emissions in 3.A Enteric Fermentation, kt CH_4

Animal species/groups	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3A Enteric Fermentation, total, incl.:	1 572.45	1 520.80	1 443.07	1 387.14	1 317.47	1 206.47	1 078.27	930.65	838.05	777.86
Mature dairy cattle	738.58	714.66	677.68	668.42	658.75	634.79	595.21	537.14	504.81	476.06
Mature non-dairy cattle	137.49	136.00	132.37	127.01	122.19	110.78	95.36	78.91	67.08	59.34
Growing cattle	585.40	565.59	535.31	499.20	451.58	387.46	325.77	262.33	219.00	197.06
Sheep	60.91	56.00	51.42	47.45	41.00	30.59	21.11	14.90	11.09	9.19
Swine	29.53	27.95	25.51	23.60	21.93	20.32	18.29	15.54	14.67	15.12
Fur-bearing animals	0.14	0.14	0.14	0.14	0.14	0.12	0.11	0.09	0.08	0.07
Rabbits	4.27	4.38	4.55	4.79	4.78	4.60	4.27	3.94	3.88	3.95
Camels	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Mules and asses	0.19	0.19	0.19	0.19	0.15	0.15	0.14	0.13	0.13	0.12
Buffaloes	0.047	0.046	0.044	0.041	0.039	0.037	0.035	0.033	0.030	0.028
Horses	13.43	13.10	12.82	12.81	13.07	13.43	13.58	13.41	13.12	12.77
Goats	2.45	2.73	3.03	3.46	3.82	4.18	4.36	4.19	4.12	4.13

Animal species/groups	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
3A Enteric Fermentation, total, incl.:	710.41	687.65	683.87	629.19	569.07	534.91	509.64	472.64	437.05	420.14
Mature dairy cattle	443.72	437.96	434.92	407.02	382.67	362.70	340.57	314.65	294.32	283.51
Mature non-dairy cattle	50.09	43.99	41.49	36.31	30.75	27.81	25.67	23.05	20.32	19.04
Growing cattle	173.99	164.22	164.53	144.83	118.10	108.42	106.89	98.55	87.16	81.77
Sheep	8.26	7.92	7.84	7.48	7.59	7.44	7.79	8.59	9.30	9.79
Swine	13.29	12.02	13.18	12.39	10.34	10.14	11.33	11.31	10.16	10.58
Fur-bearing animals	0.05	0.04	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.08
Rabbits	3.91	4.01	4.23	4.04	3.71	3.73	3.72	3.62	3.68	3.85
Camels	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
Mules and asses	0.12	0.12	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Buffaloes	0.026	0.024	0.022	0.020	0.017	0.015	0.013	0.011	0.009	0.006
Horses	12.59	12.55	12.40	11.89	11.05	10.31	9.80	9.29	8.67	8.18
Goats	4.34	4.77	5.08	5.00	4.65	4.13	3.62	3.34	3.19	3.17

Animal species/groups	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3A Enteric Fermentation, total, incl.:	402.16	389.28	393.91	396.92	379.74	359.46	351.72	344.23	332.41	315.05
Mature dairy cattle	272.92	266.49	266.77	265.70	257.98	247.28	241.11	235.73	227.93	217.03
Mature non-dairy cattle	17.76	16.79	16.50	16.20	15.36	14.20	13.28	12.44	12.05	11.11
Growing cattle	74.86	70.03	75.35	79.76	72.23	65.43	65.91	65.83	63.27	58.96
Sheep	10.01	9.88	9.63	9.48	9.05	8.51	8.12	8.08	8.05	7.66
Swine	11.65	11.50	11.21	11.62	11.63	11.18	10.68	9.96	9.48	9.19
Fur-bearing animals	0.08	0.09	0.11	0.09	0.08	0.07	0.07	0.08	0.11	0.11
Rabbits	3.84	3.85	3.96	3.99	3.92	3.80	3.75	3.67	3.58	3.49
Camels	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Mules and asses	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Buffaloes	0.004	0.003	0.003	0.003	0.003	0.003	0.004	0.006	0.006	0.006
Horses	7.72	7.29	6.95	6.58	6.08	5.68	5.46	5.09	4.67	4.30
Goats	3.17	3.19	3.28	3.33	3.24	3.14	3.18	3.18	3.10	3.02

Animal species/groups	2020	2021
3A Enteric Fermentation, total, incl.:	297.88	281.92
Mature dairy cattle	205.69	195.19
Mature non-dairy cattle	10.36	9.67
Growing cattle	54.91	50.96
Sheep	7.35	7.20
Swine	9.08	8.99
Fur-bearing animals	0.10	0.09
Rabbits	3.42	3.37
Camels	0.04	0.04
Mules and asses	0.12	0.12
Buffaloes	0.006	0.005
Horses	3.92	3.53
Goats	2.89	2.75

Table A3.2.9.2. GHG emissions in 3.B Manure Management, kt

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Methane emissions										
3.B.1 Manure Management, total, incl.	140.04	133.62	116.09	105.22	92.43	92.74	80.86	65.24	57.66	55.69
Mature dairy cattle	46.65	45.09	38.80	36.68	33.41	29.46	26.49	21.17	18.69	17.50
Mature non-dairy cattle	9.86	9.81	8.63	8.03	7.15	5.89	4.85	3.39	2.62	2.30
Growing cattle	30.28	29.42	25.34	22.88	19.13	14.99	12.12	8.29	6.32	5.65
Sheep	1.79	1.65	1.51	1.38	1.19	0.88	0.59	0.42	0.31	0.25
Swine	35.81	32.33	27.35	23.25	19.93	31.04	27.34	23.30	21.11	21.35
Poultry	13.54	13.22	12.34	10.85	9.46	8.33	7.38	6.69	6.70	6.76
Buffaloes	0.0043	0.0042	0.0040	0.0038	0.0036	0.0034	0.0032	0.0030	0.0028	0.0026
Goats	0.06	0.07	0.08	0.09	0.10	0.11	0.11	0.11	0.11	0.11
Camels	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
Horses	1.16	1.14	1.11	1.11	1.13	1.16	1.18	1.16	1.14	1.11
Mules and asses	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fur-bearing animals	0.38	0.38	0.38	0.38	0.37	0.34	0.29	0.25	0.22	0.18
Rabbits	0.49	0.50	0.52	0.55	0.55	0.53	0.49	0.45	0.44	0.45
Nitrous oxide emissions										
3.B.2 Manure Management, total, incl.	10.99	10.48	9.60	9.15	8.79	7.77	6.74	5.43	5.03	4.96
Direct emissions (total)*	6.32	6.03	5.56	5.34	5.18	4.57	3.98	3.21	2.98	2.93
Uncovered anaerobic lagoon	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Liquid system with natural crust cover	1.52	1.39	1.04	0.89	0.68	0.45	0.33	0.16	0.10	0.09
Solid storage	4.56	4.42	4.32	4.27	4.34	4.05	3.58	3.01	2.83	2.78
Composting	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01
Poultry manure without litter	0.09	0.08	0.08	0.07	0.06	0.05	0.04	0.04	0.04	0.04
Pit storage below animal con-finements	0.00007	0.00007	0.00007	0.00007	0.00006	0.00006	0.00005	0.00005	0.00005	0.00005
Aerobic treatment	0.11	0.10	0.09	0.09	0.07	NO	NO	NO	NO	NO
Indirect emissions (total)*	4.67	4.45	4.04	3.81	3.61	3.19	2.77	2.22	2.05	2.03
Volatilization	4.67	4.45	4.04	3.81	3.61	3.19	2.77	2.22	2.05	2.03
NMVOC emissions										
3.B.2 Manure Management, total, incl.	198.77	193.69	184.88	174.77	163.68	150.02	135.45	119.53	109.46	103.79

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Mature dairy cattle	68.02	66.95	65.66	64.92	63.96	61.76	58.35	53.26	48.71	45.35
Mature non-dairy cattle	13.88	13.65	13.24	12.76	12.29	11.14	9.54	7.92	6.76	5.99
Growing cattle	52.18	50.14	47.04	43.82	39.40	33.65	28.19	22.65	18.81	16.86
Swine	12.13	11.51	10.59	9.87	9.24	8.61	7.75	6.49	6.13	6.38
Sheep	1.39	1.28	1.17	1.07	0.92	0.68	0.46	0.32	0.23	0.19
Buffaloes	0.0036	0.0035	0.0034	0.0032	0.0030	0.0029	0.0027	0.0025	0.0024	0.0022
Goats	0.27	0.30	0.33	0.38	0.41	0.45	0.47	0.45	0.45	0.45
Camels	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Horses	3.19	3.11	3.04	3.04	3.10	3.19	3.23	3.19	3.12	3.03
Mules and asses	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Fur-bearing animals	1.09	1.09	1.09	1.09	1.06	0.96	0.84	0.71	0.62	0.52
Rabbits	0.36	0.37	0.38	0.40	0.40	0.39	0.36	0.33	0.33	0.33
Poultry	46.23	45.25	42.30	37.39	32.88	29.17	26.24	24.19	24.30	24.66

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Methane emissions										
3.B.1 Manure Management, total, incl.	48.02	45.06	48.01	45.14	40.08	41.28	43.44	44.34	43.73	45.30
Mature dairy cattle	15.45	15.18	15.02	13.99	13.11	12.39	11.92	10.99	10.38	10.04
Mature non-dairy cattle	1.76	1.54	1.45	1.26	1.07	0.96	0.94	0.84	0.76	0.72
Growing cattle	4.55	4.26	4.26	3.73	3.03	2.77	2.88	2.64	2.37	2.23
Sheep	0.23	0.22	0.22	0.21	0.21	0.20	0.21	0.23	0.25	0.26
Swine	17.65	15.19	17.76	16.59	13.31	15.15	17.37	19.35	19.44	21.02
Poultry	6.60	6.87	7.49	7.59	7.68	8.18	8.54	8.73	9.03	9.57
Buffaloes	0.0024	0.0022	0.0020	0.0018	0.0016	0.0014	0.0012	0.0010	0.0008	0.0006
Goats	0.11	0.12	0.13	0.13	0.12	0.11	0.09	0.09	0.08	0.08
Camels	0.0009	0.0009	0.0009	0.0009	0.0009	0.0012	0.0013	0.0013	0.0013	0.0013
Horses	1.09	1.09	1.07	1.03	0.96	0.89	0.85	0.80	0.75	0.71
Mules and asses	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fur-bearing animals	0.13	0.11	0.12	0.14	0.16	0.19	0.20	0.23	0.24	0.22
Rabbits	0.45	0.46	0.48	0.46	0.42	0.43	0.43	0.41	0.42	0.44
Nitrous oxide emissions										
3.B.2 Manure Management, total, incl.	4.45	4.28	4.53	4.29	3.85	3.75	3.83	3.69	3.47	3.56

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Direct emissions (total)*	2.65	2.55	2.68	2.53	2.27	2.19	2.20	2.10	1.97	2.00
Uncovered anaerobic lagoon	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Liquid system with natural crust cover	0.04	0.04	0.05	0.05	0.04	0.05	0.06	0.06	0.07	0.08
Solid storage	2.56	2.47	2.58	2.43	2.18	2.09	2.09	1.98	1.84	1.85
Composting	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Poultry manure without litter	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06
Pit storage below animal con-finements	0.00005	0.00005	0.00004	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Aerobic treatment	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Indirect emissions (total)*	1.81	1.73	1.85	1.76	1.59	1.57	1.63	1.58	1.50	1.55
Volatilization	1.81	1.73	1.85	1.76	1.59	1.57	1.63	1.58	1.50	1.55
NMVOC emissions										
3.B.2 Manure Management, total, incl.	95.76	92.45	93.70	88.68	81.67	78.92	77.32	74.34	71.23	70.83
Mature dairy cattle	41.80	39.74	38.76	36.21	33.03	30.42	28.09	25.92	23.95	22.50
Mature non-dairy cattle	5.07	4.47	4.22	3.70	3.13	2.81	2.57	2.31	2.05	1.92
Growing cattle	14.77	13.83	13.82	12.15	9.88	9.04	8.88	8.15	7.20	6.73
Swine	5.61	5.08	5.55	5.21	4.37	4.29	4.77	4.72	4.23	4.44
Sheep	0.17	0.16	0.16	0.16	0.15	0.15	0.15	0.17	0.18	0.19
Buffaloes	0.0020	0.0018	0.0017	0.0015	0.0013	0.0012	0.0010	0.0008	0.0007	0.0005
Goats	0.47	0.52	0.55	0.54	0.50	0.45	0.39	0.36	0.35	0.34
Camels	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Horses	2.99	2.98	2.94	2.82	2.62	2.45	2.33	2.21	2.06	1.94
Mules and asses	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Fur-bearing animals	0.37	0.30	0.34	0.40	0.47	0.53	0.58	0.66	0.67	0.62
Rabbits	0.33	0.34	0.36	0.34	0.31	0.31	0.31	0.30	0.31	0.32
Poultry	24.16	25.00	26.97	27.13	27.17	28.44	29.21	29.52	30.20	31.81

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Methane emissions										
3.B.1 Manure Management, total, incl.	48.56	48.80	49.53	49.81	47.75	45.05	43.12	43.81	41.86	40.17
Mature dairy cattle	9.71	9.42	9.47	9.48	9.25	8.90	8.72	8.49	8.25	7.89
Mature non-dairy cattle	0.68	0.63	0.62	0.62	0.60	0.55	0.52	0.48	0.48	0.44

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Growing cattle	2.06	1.91	2.04	2.16	1.98	1.81	1.83	1.82	1.78	1.66
Sheep	0.27	0.27	0.26	0.26	0.25	0.23	0.22	0.22	0.22	0.21
Swine	24.20	24.70	25.03	24.50	22.75	20.94	19.63	20.59	18.58	17.04
Poultry	10.24	10.45	10.67	11.41	11.64	11.39	11.02	11.03	11.36	11.77
Buffaloes	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0005	0.0006	0.0006
Goats	0.08	0.08	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08
Camels	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
Horses	0.67	0.63	0.60	0.57	0.53	0.49	0.47	0.44	0.40	0.37
Mules and asses	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fur-bearing animals	0.21	0.25	0.29	0.26	0.23	0.20	0.19	0.23	0.29	0.29
Rabbits	0.44	0.44	0.45	0.46	0.45	0.43	0.43	0.42	0.41	0.40
Nitrous oxide emissions										
3.B.2 Manure Management, total, incl.	3.64	3.58	3.61	3.70	3.67	3.52	3.44	3.34	3.43	3.33
Direct emissions (total)*	2.02	1.99	2.00	2.03	2.01	1.93	1.89	1.83	1.88	1.81
Uncovered anaerobic lagoon	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Liquid system with natural crust cover	0.11	0.12	0.12	0.14	0.15	0.16	0.17	0.17	0.18	0.19
Solid storage	1.84	1.79	1.80	1.81	1.76	1.67	1.62	1.57	1.60	1.52
Composting	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02
Poultry manure without litter	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.07	0.08	0.08
Pit storage below animal con-finements	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Aerobic treatment	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Indirect emissions (total)*	1.61	1.60	1.61	1.66	1.66	1.59	1.55	1.51	1.55	1.52
Volatilization	1.61	1.60	1.61	1.66	1.66	1.59	1.55	1.51	1.55	1.52
NMVOC emissions										
3.B.2 Manure Management, total, incl.	71.59	71.19	71.63	73.84	73.10	69.85	67.75	66.79	66.64	66.24
Mature dairy cattle	21.60	20.98	20.67	20.37	19.53	18.53	17.97	17.38	16.63	15.71
Mature non-dairy cattle	1.80	1.70	1.67	1.64	1.56	1.44	1.34	1.25	1.18	1.08
Growing cattle	6.15	5.76	6.18	6.53	5.89	5.34	5.33	5.26	5.00	4.67
Swine	4.88	4.79	4.67	4.84	4.85	4.67	4.45	4.14	3.94	3.82
Sheep	0.19	0.19	0.18	0.18	0.17	0.16	0.16	0.16	0.16	0.15
Buffaloes	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0005	0.0005	0.0005

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Goats	0.34	0.35	0.36	0.36	0.35	0.34	0.35	0.34	0.34	0.33
Camels	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Horses	1.83	1.73	1.65	1.56	1.44	1.35	1.30	1.21	1.11	1.02
Mules and asses	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Fur-bearing animals	0.59	0.71	0.82	0.74	0.65	0.58	0.53	0.66	0.82	0.84
Rabbits	0.32	0.32	0.33	0.34	0.33	0.32	0.32	0.31	0.30	0.29
Poultry	33.86	34.64	35.09	37.27	38.30	37.10	36.00	36.07	37.16	38.31

Category	2020	2021
Methane emissions		
3.B.1 Manure Management, total, incl.	39.46	39.41
Mature dairy cattle	7.52	7.18
Mature non-dairy cattle	0.41	0.39
Growing cattle	1.56	1.47
Sheep	0.20	0.20
Swine	17.26	18.25
Poultry	11.43	10.90
Buffaloes	0.0005	0.0005
Goats	0.08	0.07
Camels	0.0013	0.0013
Horses	0.34	0.31
Mules and asses	0.01	0.01
Fur-bearing animals	0.26	0.25
Rabbits	0.39	0.39
Nitrous oxide emissions		
3.B.2 Manure Management, total, incl.	3.22	3.10
Direct emissions (total)*	1.75	1.68
Uncovered anaerobic lagoon	NA	NA
Liquid system with natural crust cover	0.20	0.20
Solid storage	1.45	1.38
Composting	0.02	0.02

Category	2020	2021
Poultry manure without litter	0.08	0.07
Pit storage below animal confinements	0.00005	0.00005
Aerobic treatment	NO	NO
Indirect emissions (total)*	1.47	1.41
Volatilization	1.47	1.41
NMVOC emissions		
3.B.2 Manure Management, total, incl.	63.42	60.15
Mature dairy cattle	14.71	13.77
Mature non-dairy cattle	1.00	0.92
Growing cattle	4.33	4.01
Swine	3.77	3.73
Sheep	0.14	0.14
Buffaloes	0.0004	0.0004
Goats	0.31	0.30
Camels	0.0002	0.0002
Horses	0.93	0.84
Mules and asses	0.02	0.02
Fur-bearing animals	0.74	0.73
Rabbits	0.29	0.28
Poultry	37.17	35.40

* – *emissions from manure in Pasture/Range/Paddock are reported in 3.D Agricultural Soils*

Table A3.2.9.3. Methane emissions in 3.C Rice Cultivation, kt CH_4

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Annual methane emissions from rice cultivation	8,66	7,08	7,42	7,06	6,74	6,61	6,89	6,69	6,18	6,54

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Annual methane emissions from rice cultivation	7,48	5,63	5,63	6,65	6,33	6,34	6,44	6,27	5,87	7,28

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Annual methane emissions from rice cultivation	8.69	8.80	7.67	7.17	3.02	3.47	3.56	3.76	3.74	3.11

Category	2020	2021
Annual methane emissions from rice cultivation	3.32	2.99

Table A3.2.9.4. Nitrous oxide emissions in 3.D Agricultural Soils, kt N_2O

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3.D.1.1 Inorganic N Fertilizers	28.89	24.58	20.25	15.93	12.57	9.21	5.85	6.50	6.39	5.13
3.D.1.2 Organic N Fertilizers	7.78	7.42	6.83	6.51	6.30	5.62	4.87	3.93	3.61	3.51
3.D.1.3 Urine and Dung Deposited by Grazing Animals	10.59	10.09	9.87	9.81	9.60	8.71	7.87	6.80	6.46	6.17
3.D.1.4 Crop Residues	46.26	44.15	42.75	44.04	35.98	34.79	29.03	30.39	26.79	22.48
3.D.1.5 Mineralization/Immobiliza-tion Associated with Loss/Gain of Soil Organic Matter	NO	NO	NO	0.22	NO	0.93	0.93	4.05	2.18	2.45
3.D.1.6 Cultivation of Organic Soils	5.99	6.05	6.10	6.11	6.13	6.13	6.13	6.13	6.13	6.13
3.D.2.1 Atmospheric Deposition	6.93	6.17	5.40	4.70	4.14	3.41	2.68	2.47	2.35	2.12
3.D.2.2 Nitrogen Leaching and Run-off	19.99	18.40	16.95	16.23	13.53	12.45	10.12	10.93	9.56	8.31

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
3.D.1.1 Inorganic N Fertilizers	3.48	4.98	4.90	4.25	5.71	5.89	7.30	9.05	11.53	9.94
3.D.1.2 Organic N Fertilizers	3.17	3.05	3.17	3.00	2.71	2.61	2.62	2.50	2.33	2.36
3.D.1.3 Urine and Dung Deposited by Grazing Animals	5.92	5.80	5.84	5.50	5.06	4.81	4.50	4.16	3.90	3.89
3.D.1.4 Crop Residues	22.25	22.42	21.56	18.27	21.60	20.90	20.99	18.40	24.23	22.75
3.D.1.5 Mineralization/Immobiliza-tion Associated with Loss/Gain of Soil Organic Matter	5.00	7.08	7.19	4.01	8.42	8.94	7.33	4.84	12.25	11.26
3.D.1.6 Cultivation of Organic Soils	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13	6.13
3.D.2.1 Atmospheric Deposition	1.78	1.96	1.98	1.82	1.92	1.90	2.07	2.27	2.57	2.35
3.D.2.2 Nitrogen Leaching and Run-off	8.36	9.16	9.00	7.33	9.28	9.22	9.16	8.35	11.82	10.91

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3.D.1.1 Inorganic N Fertilizers	12.13	14.08	14.55	16.32	16.53	15.94	19.26	21.92	24.89	25.62
3.D.1.2 Organic N Fertilizers	2.39	2.34	2.36	2.40	2.37	2.27	2.21	2.15	2.22	2.15
3.D.1.3 Urine and Dung Deposited by Grazing Animals	3.73	3.64	3.74	3.75	3.65	3.51	3.42	3.38	3.68	3.49
3.D.1.4 Crop Residues	22.65	28.03	26.54	31.31	31.63	30.15	32.88	30.93	34.65	35.16
3.D.1.5 Mineralization/Immobiliza-tion Associated with Loss/Gain of Soil Organic Matter	8.35	14.93	12.29	17.50	18.29	16.76	18.61	15.38	18.43	19.74

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3.D.1.6 Cultivation of Organic Soils	6.13	6.13	6.13	6.01	6.01	6.01	6.01	6.01	5.97	5.94
3.D.2.1 Atmospheric Deposition	2.65	2.91	3.00	3.26	3.27	3.15	3.61	3.98	4.45	4.52
3.D.2.2 Nitrogen Leaching and Run-off	10.72	13.82	13.02	15.67	15.93	15.09	16.84	16.26	18.50	19.03

Category	2020	2021
3.D.1.1 Inorganic N Fertilizers	30.56	31.40
3.D.1.2 Organic N Fertilizers	2.07	1.97
3.D.1.3 Urine and Dung Deposited by Grazing Animals	3.33	3.17
3.D.1.4 Crop Residues	31.22	37.59
3.D.1.5 Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter	11.25	19.91
3.D.1.6 Cultivation of Organic Soils	5.93	5.93
3.D.2.1 Atmospheric Deposition	5.21	5.29
3.D.2.2 Nitrogen Leaching and Run-off	17.30	20.83

Table A3.2.9.5. Carbon dioxide emissions in Agricultural sector, kt CO_2

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
3.G Liming	2 592.08	1 351.26	1 351.26	1 351.26	1 351.26	1 351.26	299.20	76.41	77.79	70.63
3.H Urea Application	270.14	229.79	189.44	149.09	117.71	86.33	54.95	61.00	59.96	48.27

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
3.G Liming	63.47	71.47	53.78	49.37	83.33	90.92	105.99	112.35	124.95	151.88
3.H Urea Application	82.20	117.00	116.91	191.10	35.83	138.32	171.32	212.11	355.18	175.03

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
3.G Liming	127.46	127.16	161.72	182.25	156.26	169.83	140.09	168.60	163.74	141.37
3.H Urea Application	334.73	391.52	364.33	337.13	309.94	282.75	255.56	228.37	201.18	208.84

Category	2020	2021
3.G Liming	131.35	176.23
3.H Urea Application	235.51	235.60

A3.2.10 Recalculations

Table A3.2.10.1. Recalculation of Methane emissions in 3.A Enteric Fermentation, kt CH_4

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous NIR										
Mature dairy cattle	738.58	714.66	677.68	668.42	658.75	634.79	595.21	537.14	504.81	476.06
Other mature cattle	137.49	136.00	132.37	127.01	122.19	110.78	95.36	78.91	67.08	59.34
Growing cattle	585.40	565.59	535.31	499.20	451.58	387.46	325.77	262.33	219.00	197.06
Sheep	60.91	56.00	51.42	47.45	41.00	30.59	21.11	14.90	11.09	9.19
Other animals	50.0806	48.5599	46.3013	45.0608	43.9533	42.8590	40.8123	37.3658	36.0667	36.2125
Current NIR										
Mature dairy cattle	738.58	714.66	677.68	668.42	658.75	634.79	595.21	537.14	504.81	476.06
Other mature cattle	137.49	136.00	132.37	127.01	122.19	110.78	95.36	78.91	67.08	59.34
Growing cattle	585.40	565.59	535.31	499.20	451.58	387.46	325.77	262.33	219.00	197.06
Sheep	60.91	56.00	51.42	47.45	41.00	30.59	21.11	14.90	11.09	9.19
Other animals	50.0806	48.5599	46.3013	45.0608	43.9533	42.8590	40.8123	37.3658	36.0667	36.2125

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous NIR										
Mature dairy cattle	443.72	437.96	434.92	407.02	382.67	362.70	340.57	314.65	294.32	283.51
Other mature cattle	50.09	43.99	41.49	36.31	30.75	27.81	25.67	23.05	20.32	19.04
Growing cattle	173.99	164.22	164.53	144.83	118.10	108.42	106.89	98.55	87.16	81.77
Sheep	8.26	7.92	7.84	7.48	7.59	7.44	7.79	8.59	9.30	9.79
Other animals	34.3517	33.5623	35.0962	33.5462	29.9726	28.5474	28.7245	27.8061	25.9542	26.0215
Current NIR										
Mature dairy cattle	443.72	437.96	434.92	407.02	382.67	362.70	340.57	314.65	294.32	283.51
Other mature cattle	50.09	43.99	41.49	36.31	30.75	27.81	25.67	23.05	20.32	19.04
Growing cattle	173.99	164.22	164.53	144.83	118.10	108.42	106.89	98.55	87.16	81.77
Sheep	8.26	7.92	7.84	7.48	7.59	7.44	7.79	8.59	9.30	9.79
Other animals	34.3517	33.5623	35.0962	33.5462	29.9726	28.5474	28.7245	27.8061	25.9542	26.0215

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Previous NIR										
Mature dairy cattle	272.92	266.49	266.77	265.70	257.98	247.28	241.11	235.73	227.93	217.03
Other mature cattle	17.76	16.79	16.50	16.20	15.36	14.20	13.28	12.44	12.05	11.11
Growing cattle	74.86	70.03	75.35	79.76	72.23	65.43	65.91	65.83	63.27	58.96
Sheep	10.01	9.88	9.63	9.48	9.05	8.51	8.12	8.08	8.05	7.66
Other animals	26.6164	26.0834	25.6608	25.7770	25.1152	24.0468	23.3060	22.1431	21.1003	20.2762
Current NIR										
Mature dairy cattle	272.92	266.49	266.77	265.70	257.98	247.28	241.11	235.73	227.93	217.03
Other mature cattle	17.76	16.79	16.50	16.20	15.36	14.20	13.28	12.44	12.05	11.11
Growing cattle	74.86	70.03	75.35	79.76	72.23	65.43	65.91	65.83	63.27	58.96
Sheep	10.01	9.88	9.63	9.48	9.05	8.51	8.12	8.08	8.05	7.66
Other animals	26.6164	26.0834	25.6608	25.7770	25.1152	24.0468	23.3060	22.1431	21.1016	20.2774

Category	2020	2021
Previous NIR		
Mature dairy cattle	205.69	
Other mature cattle	10.36	
Growing cattle	54.91	
Sheep	7.35	
Other animals	19.5790	
Current NIR		
Mature dairy cattle	205.69	195.19
Other mature cattle	10.36	9.67
Growing cattle	54.91	50.96
Sheep	7.35	7.20
Other animals	19.5805	18.8999

Table A3.2.10.2. Recalculations of GHG emissions in 3.B Manure Management category, kt

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous NIR										
CH_4 emissions	140.0389	133.6199	116.0866	105.2216	92.4327	92.7441	80.8637	65.2435	57.6622	55.6884
N_2O emissions	10.9859	10.4812	9.5964	9.1505	8.7885	7.7678	6.7439	5.4314	5.0304	4.9571
NMVOC emissions	198.7666	193.6887	184.8832	174.7705	163.6834	150.0167	135.4501	119.5334	109.4644	103.7867
Current NIR										
CH_4 emissions	140.0389	133.6199	116.0866	105.2216	92.4327	92.7441	80.8637	65.2435	57.6622	55.6884
N_2O emissions	10.9859	10.4812	9.5964	9.1505	8.7885	7.7678	6.7439	5.4314	5.0304	4.9571
NMVOC emissions	198.7666	193.6887	184.8832	174.7705	163.6834	150.0167	135.4501	119.5334	109.4644	103.7867

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous NIR										
CH_4 emissions	48.0216	45.0577	48.0073	45.1431	40.0805	41.2831	43.4397	44.3371	43.7322	45.3040
N_2O emissions	4.4527	4.2839	4.5310	4.2940	3.8523	3.7537	3.8285	3.6851	3.4677	3.5559
NMVOC emissions	95.7629	92.4468	93.7001	88.6816	81.6661	78.9190	77.3161	74.3365	71.2291	70.8345
Current NIR										
CH_4 emissions	48.0216	45.0577	48.0073	45.1431	40.0805	41.2831	43.4397	44.3371	43.7322	45.3040
N_2O emissions	4.4527	4.2839	4.5310	4.2940	3.8523	3.7537	3.8285	3.6851	3.4677	3.5559
NMVOC emissions	95.7629	92.4468	93.7001	88.6816	81.6661	78.9190	77.3161	74.3365	71.2291	70.8345

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Previous NIR										
CH_4 emissions	48.5619	48.7957	49.5275	49.8114	47.7543	45.0504	43.1223	43.8118	41.8615	40.1656
N_2O emissions	3.6368	3.5807	3.6097	3.6951	3.6725	3.5218	3.4354	3.3430	3.4279	3.3284
NMVOC emissions	71.5862	71.1859	71.6349	73.8407	73.1049	69.8539	67.7487	66.7918	66.6437	66.2395
Current NIR										
CH_4 emissions	48.5619	48.7957	49.5275	49.8114	47.7543	45.0504	43.1223	43.8119	41.8616	40.1657
N_2O emissions	3.6368	3.5807	3.6097	3.6951	3.6725	3.5218	3.4354	3.3430	3.4279	3.3285
NMVOC emissions	71.5862	71.1859	71.6349	73.8407	73.1049	69.8539	67.7487	66.7918	66.6438	66.2397

Category	2020	2021
Previous NIR		
CH_4 emissions	39.4603	
N_2O emissions	3.2153	
NMVOC emissions	63.4199	
Current NIR		
CH_4 emissions	39.4603	39.4124
N_2O emissions	3.2153	3.0954
NMVOC emissions	63.4201	60.1480

Table A3.2.10.3. Recalculations of Nitrous oxide emissions in category 3.D Agricultural Soils, kt N_2O

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Previous NIR										
Direct N_2O emissions	99.51671	92.29725	85.81228	82.63488	70.59186	65.38080	54.68279	57.80008	51.55675	45.87667
Indirect N_2O emissions	26.92013	24.57353	22.34916	20.93019	17.67190	15.85983	12.80196	13.40200	11.90848	10.42695
Current NIR										
Direct N_2O emissions	99.51671	92.29725	85.81228	82.63488	70.59186	65.38080	54.68279	57.80008	51.55675	45.87667
Indirect N_2O emissions	26.92013	24.57353	22.34916	20.93019	17.67190	15.85983	12.80196	13.40200	11.90848	10.42695

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Previous NIR										
Direct N_2O emissions	45.94968	49.46243	48.79557	41.16658	49.63511	49.28298	48.86541	45.08568	60.37819	56.33731
Indirect N_2O emissions	10.13866	11.12056	10.98439	9.14287	11.20094	11.12518	11.23737	10.61912	14.38799	13.25779
Current NIR										
Direct N_2O emissions	45.94968	49.46243	48.79557	41.16658	49.63511	49.28298	48.86541	45.08568	60.37819	56.33731
Indirect N_2O emissions	10.13866	11.12056	10.98439	9.14287	11.20094	11.12518	11.23737	10.61912	14.38799	13.25779

Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Previous NIR										
Direct N_2O emissions	55.38860	69.14751	65.62746	77.29591	78.47335	74.63827	82.40097	79.78797	89.83123	92.10917
Indirect N_2O emissions	13.36812	16.73840	16.01137	18.92830	19.20278	18.23546	20.45044	20.23654	22.94807	23.55329
Current NIR										
Direct N_2O emissions	55.38860	69.14751	65.62746	77.29591	78.47335	74.63827	82.40097	79.78797	89.83126	92.10920
Indirect N_2O emissions	13.36812	16.73840	16.01137	18.92830	19.20278	18.23546	20.45044	20.23654	22.94808	23.55330

Category	2020	2021
Previous NIR		
Direct N_2O emissions	84.35409	
Indirect N_2O emissions	22.51015	
Current NIR		
Direct N_2O emissions	84.35410	99.96670
Indirect N_2O emissions	22.51015	26.12402

A3.3 Land Use, Land Use Change and Forestry (CRF Sector 4)

A3.3.1 Methodological issues of the land-use category Forest land

Calculation of total annual GHG emissions/removals in the forestry sector was held for the two categories of Forest and: a) for Forest land remaining forest land; b) for Land converted to forest land.

Activity data for the Forest land category were obtained from national statistical reporting form 16-zem (previously 6-zem). For afforestation (Land converted to forest land), the land-use change matrix was used (Table 6.2) and the actual data of afforestation (database). The land-use change matrix is used to determine "conversion vectors" of land areas at change of land-use categories, since there is no data in national statistics on the land-use categories from which conversion takes place.

In the table A3.3.1 the areas of Forest land remaining Forest land are presented with subdivision on actually covered with forest vegetation and unstocked (temporary or permanently). Only areas actually covered with forest vegetation (stocked) were used to calculate C-gains due to forest growth.

Table A3.3.1. Areas covered by forest vegetation and unstocked areas

Year	Area of Forest land remaining Forest land, kha			
	Total area of the category	Unmanaged forests	Areas of managed Forest land	
			Stocked	Unstocked and other
1990	10 211.95	31.40	9 201.73	1 010.22
1991	10 230.85	31.40	9 228.25	1 002.60
1992	10 282.73	31.40	9 224.95	1 057.78
1993	10 299.97	31.40	9 262.85	1 037.12
1994	10 314.62	31.40	9 289.50	1 025.12
1995	10 312.69	31.40	9 314.05	998.64
1996	10 317.84	31.40	9 318.35	999.49
1997	10 318.63	31.40	9 327.85	990.78
1998	10 331.65	31.40	9 329.55	1 002.10
1999	10 333.10	31.40	9 359.33	973.77
2000	10 338.40	31.40	9 388.47	949.93
2001	10 345.95	31.40	9 396.42	949.53
2002	10 351.79	31.40	9 421.89	929.90
2003	10 365.21	31.40	9 433.34	931.87
2004	10 376.16	31.40	9 441.43	934.73
2005	10 396.29	31.40	9 466.35	929.94
2006	10 411.90	31.40	9 498.50	913.40
2007	10 403.65	31.40	9 510.80	892.85
2008	10 389.16	31.40	9 505.45	883.71
2009	10 373.12	31.40	9 512.29	860.83
2010	10 368.55	31.40	9 517.46	851.10
2011	10 364.11	31.40	9 526.71	837.41
2012	10 362.35	31.40	9 531.66	830.70
2013	10 358.38	31.40	9 521.43	836.95
2014	10 365.60	31.40	9 506.93	858.67
2015	10 370.69	31.40	9 489.07	881.62
2016	10 409.01	31.40	9 458.78	950.22
2017	10 425.85	31.40	9 447.06	978.79
2018	10 394.19	31.40	9 466.06	928.14
2019	10 397.04	31.40	9 451.56	945.48
2020	10 402.05	31.40	9 442.61	959.44
2021	10 407.10	31.40	9 442.61	933.09

Actual data on afforestation and deforestation were used from the database. The information is presented based on the cumulative approach and 20-years transition period - Table A3.3.2.

Table A3.3.2. Land areas converted to and from the land-use category Forest land on cumulative basis, kha

To forests						
Year	Cropland	Grassland	Wetlands	Settlements	Other land	Total
1990	9.55	0.00	0.00	0.00	0.00	9.55
1991	15.92	0.00	0.00	0.61	0.83	17.35
1992	15.92	0.51	0.00	3.52	3.92	23.87
1993	21.08	0.51	0.00	3.52	5.92	31.03
1994	26.77	0.51	0.00	3.52	6.78	37.58
1995	28.83	0.51	0.00	8.99	6.78	45.11
1996	36.97	0.51	0.18	8.99	7.50	54.16
1997	43.94	0.51	0.18	8.99	7.94	61.57
1998	45.37	0.51	0.18	8.99	10.89	65.95
1999	48.35	0.51	0.18	8.99	12.16	70.20
2000	53.19	0.51	0.27	9.07	12.16	75.20
2001	57.37	0.51	0.27	9.94	12.16	80.25
2002	62.70	0.51	0.51	9.94	13.46	87.11
2003	67.21	0.51	0.51	10.32	13.73	92.29
2004	74.29	0.58	0.51	10.63	13.73	99.74
2005	78.84	3.70	0.51	10.63	13.73	107.41
2006	94.52	8.61	0.51	10.63	13.73	128.00
2007	110.78	13.18	0.51	10.63	17.55	152.65
2008	119.18	28.05	0.51	10.63	22.57	180.94
2009	133.20	48.64	0.51	10.63	25.79	218.78
2010	138.80	55.32	0.51	10.63	27.29	232.54
2011	141.41	62.72	0.51	10.03	32.52	247.18
2012	145.52	75.31	0.51	7.11	30.60	259.05
2013	140.37	88.93	0.51	7.11	28.87	265.78
2014	136.52	91.03	0.51	7.11	29.51	264.68
2015	134.25	93.73	0.61	1.64	29.51	259.74
2016	134.40	98.98	0.43	1.64	45.95	281.40
2017	129.77	104.27	0.43	1.64	49.02	285.14
2018	128.35	111.82	0.49	1.64	49.08	291.37
2019	125.36	113.79	0.89	1.64	48.08	289.75
2020	120.52	115.77	0.80	1.57	48.63	287.29
2021	116.34	118.22	0.80	0.70	49.39	285.45
From forests to other categories						
Year	Cropland	Grassland	Wetlands	Settlements	Other land	Total
1990	0.04	0.01	0.00	0.08	0.01	0.14
1991	0.14	0.02	0.00	0.28	0.04	0.48
1992	2.94	0.50	0.04	5.98	0.93	10.39
1993	2.94	0.54	0.04	6.00	0.93	10.46
1994	2.95	0.54	0.04	6.01	0.93	10.47
1995	2.96	0.55	0.06	6.03	0.98	10.58
1996	3.07	2.32	0.22	7.48	1.49	14.58
1997	3.09	2.35	0.22	7.48	1.52	14.66
1998	3.09	3.75	2.63	27.51	1.52	38.50
1999	3.09	3.77	2.65	27.53	1.52	38.56
2000	3.11	3.90	2.65	27.53	1.62	38.81
2001	3.16	3.98	2.66	27.56	1.65	39.02
2002	3.16	4.17	2.67	27.96	1.65	39.61
2003	3.26	4.17	2.73	27.96	1.73	39.85
2004	3.85	4.17	2.73	28.21	1.83	40.80
2005	3.86	4.19	2.75	28.29	1.83	40.93
2006	3.86	4.27	2.75	28.37	1.86	41.10
2007	3.86	4.28	2.86	28.46	2.01	41.47
2008	3.86	4.28	2.86	36.41	2.01	49.41
2009	3.87	4.28	2.86	36.43	2.01	49.45
2010	3.83	4.27	2.86	36.35	2.00	49.31
2011	3.73	4.25	2.86	36.25	1.97	49.06
2012	0.93	3.77	2.83	30.94	1.09	39.55

2013	0.93	3.73	2.82	31.01	1.08	39.57
2014	0.92	3.73	2.82	31.00	1.12	39.59
2015	0.91	3.72	2.80	30.98	1.09	39.50
2016	0.80	1.95	2.64	29.53	0.58	35.50
2017	0.78	1.92	2.64	29.53	0.61	35.49
2018	0.78	0.53	0.23	9.50	0.62	11.65
2019	0.78	0.50	0.22	9.48	0.90	11.89
2020	0.76	0.37	0.21	9.49	0.82	11.65
2021	0.71	0.30	0.20	9.47	0.79	11.46

The areas of conversions to and from forests are taken from the database as afforested and deforested lands respectively. This improves reliability of the results, since the primary data was collected at the level of individual plots of the territory on which the respective activity was implemented by quarter by every forestry enterprise in Ukraine (the so-called plot-wise information database). Moreover, the conservative principle is thus ensured, because form 16-zem takes into account only the legal fact of a change in attribution to a certain land-use category, which is not in line with the actually performed afforestation or deforestation activities.

Thus, information about the area of land converted to forest land from the land-use change matrix was used to determine proportional ratios among donor categories for the land-use category Forest Land. This was done because national statistical reporting, as well as land plot logs at forestry enterprises for the period since 1990 do not reflect information on the land-use categories from and/or into which plots of forest land were converted. Based on those ratios, the values from the database were distributed. Thus, special attention was paid to maintaining the balance of territories with use of the forest land not covered in the estimation. The areas of sub-categories indicated in the land-use category are shown in the reporting tables [12].

Donor categories are defined annually based on comparison of total areas of every category in year X-1 and X of form 16-zem. Consequently, donor categories might change from year to year.

For all the other land-use categories (including the categories Cropland and Grassland) for land converted to categories, information on the areas from statistical reporting form 16-zem, as well as the land-use change matrix was used (Table 6.4).

Estimations of carbon emissions/removals were made in the context of sub-categories 4.A.1 Forest land remaining forest and 4.A.2 Land converted to forest land. In sub-category 4.A.1, emissions/removals were estimated only for managed forests in living biomass based on age structure of stands. Since databases with detailed information about forest features are available mostly for the forests under management of the State Forest Resources Agency of Ukraine, the calculations were performed based on that data and then extrapolated to entire area of forest covered lands excluding unmanaged forests.

The ERT recommended to revise estimations for DOM category by developing more accurate and mutually consistent EFs for litter and deadwood. Development of EFs is an important step recognized by including it into improvement plan but in the current submission conservative decision is taken to apply Tier 1. Thus, it is assumed zero CSC in continuously forested areas until new methodology and EFs will be developed.

For forest soils, the decision on the zero-carbon balance was made, based on the studies [5].

The annual increase in carbon stocks in living biomass of Forest land remaining forest land was estimated under equation 2.9 of the 2006 IPCC Guidelines in the context of the key forest tree species, climatic zones and with consideration of age structure.

The classification (Table A3.3.3) was used for distribution of areas into natural zones.

Table A3.3.3. Distribution of the forest area of Ukrainian regions' territory by climatic zones, relative units

Regions	Polissia (Woodland)	Forest Steppe	North Steppe	South Steppe	Carpathian Mts.	Crimean Mts.
AR Crimea				0.1		0.9
Vinnytska		1.0				
Volynska	0.8	0.2				
Dnipropetrovska			0.9	0.1		
Donetska			1.0			
Zhytomyrska	0.8	0.2				
Transcarpathian					1.0	
Zaporizhska			0.5	0.5		
Ivano-Frankivska		0.2			0.8	
Kyivska	0.7	0.3				
Kirovohradska		0.5	0.5			
Luganska			1.0			
Lvivska		0.3			0.7	
Mykolaivska			0.6	0.4		
Odesska		0.2	0.3	0.5		
Poltavska		1.0				
Rivnenska	0.8	0.2				
Sumska	0.2	0.8				
Ternopilska		1.0				
Kharkivska		0.5	0.5			
Khersonska				1.0		
Khmelnytska		1.0				
Cherkaska		1.0				
Chernivetska		0.3			0.7	
Chernihivska	0.8	0.2				

Table A3.3.4 presents national factors of above-ground biomass growth rates for the main tree species by natural zones, as well as the ratio of below-ground and above-ground biomass growth. It is based on national study [10].

Table A3.3.4. Biomass growth by natural zones and species for Forest land remaining forest land (national data), t d.m./ha/yr

	Age														
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-999
Polissia (Woodland)															
Pine	3.6	3.6	4.9	4.9	4.2	4.2	3.2	3.2	2.9	2.9	1.9	1.9	1.9	1.9	1.9
Spruce	5.5	5.5	6.9	6.9	6.0	6.0	4.7	4.7	3.2	3.2	2.0	2.0	2.0	2.0	2.0
Other conifers	4.5	4.5	5.8	5.8	5.0	5.0	3.9	3.9	3.0	3.0	1.9	1.9	1.9	1.9	1.9
Oak	2.9	2.9	4.8	4.8	4.8	4.8	3.7	3.7	2.9	2.9	2.1	2.1	2.1	2.1	2.1
Beech	1.7	1.7	7.1	7.1	6.4	6.4	5.5	5.5	4.1	4.1	2.7	2.7	2.7	2.7	2.7
Other hardwoods	2.5	2.5	5.5	5.5	5.2	5.2	4.3	4.3	3.3	3.3	2.3	2.3	2.3	2.3	2.3
Birch	2.9	2.9	3.8	3.8	3.1	3.1	2.4	2.4	1.6	1.6	0.9	0.9	0.9	0.9	0.9
Aspen	4.7	4.7	5.4	5.4	3.9	3.9	2.7	2.7	1.7	1.7	0.7	0.7	0.7	0.7	0.7
Alder	4.3	4.3	5.7	5.7	3.8	3.8	2.8	2.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0
Other softwoods	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Other tree species	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Shrubs	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Forest Steppe															
Pine	2.9	2.9	4.4	4.4	4.6	4.6	3.7	3.7	3.0	3.0	1.7	1.7	1.7	1.7	1.7
Spruce	5.8	5.8	7.3	7.3	6.4	6.4	5.0	5.0	3.6	3.6	2.2	2.2	2.2	2.2	2.2
Other conifers	4.3	4.3	5.8	5.8	5.5	5.5	4.3	4.3	3.3	3.3	1.9	1.9	1.9	1.9	1.9
Oak	2.9	2.9	4.8	4.8	4.8	4.8	3.7	3.7	2.9	2.9	2.1	2.1	2.1	2.1	2.1
Beech	1.7	1.7	7.1	7.1	6.4	6.4	5.5	5.5	4.1	4.1	2.7	2.7	2.7	2.7	2.7
Other hardwoods	2.5	2.5	5.6	5.6	5.3	5.3	4.3	4.3	3.3	3.3	2.3	2.3	2.3	2.3	2.3
Birch	2.9	2.9	3.8	3.8	3.1	3.1	2.4	2.4	1.6	1.6	0.9	0.9	0.9	0.9	0.9
Aspen	4.7	4.7	5.4	5.4	3.9	3.9	2.7	2.7	1.7	1.7	0.7	0.7	0.7	0.7	0.7
Alder	4.3	4.3	5.7	5.7	3.8	3.8	2.8	2.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0
Other softwoods	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Other tree species	*3.8*	*3.8*	*4.6*	*4.6*	*3.5*	*3.5*	*2.5*	*2.5*	*1.6*	*1.6*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Shrubs	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
North Steppe															
Pine	2.1	2.1	2.9	2.9	2.6	2.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Spruce	5.6	5.6	7.0	7.0	6.1	6.1	4.8	4.8	3.3	3.3	2.0	2.0	2.0	2.0	2.0
Other conifers	3.9	3.9	5.0	5.0	4.3	4.3	3.5	3.5	2.7	2.7	2.0	2.0	2.0	2.0	2.0
Oak	1.4	1.4	3.9	3.9	3.7	3.7	3.3	3.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Beech	1.7	1.7	7.1	7.1	6.4	6.4	5.5	5.5	4.1	4.1	2.8	2.8	2.8	2.8	2.8
Other hardwoods	1.6	1.6	5.5	5.5	5.1	5.1	4.4	4.4	3.0	3.0	2.4	2.4	2.4	2.4	2.4
Birch	2.9	2.9	3.8	3.8	3.1	3.1	2.4	2.4	1.6	1.6	0.9	0.9	0.9	0.9	0.9
Aspen	4.7	4.7	5.4	5.4	3.9	3.9	2.7	2.7	1.7	1.7	0.7	0.7	0.7	0.7	0.7

	Age														
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-999
Alder	4.3	4.3	5.7	5.7	3.8	3.8	2.8	2.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0
Other softwoods	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Other tree species	*3.8*	*3.8*	*4.6*	*4.6*	*3.5*	*3.5*	*2.5*	*2.5*	*1.6*	*1.6*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Shrubs	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
South Steppe															
Pine	2.1	2.1	2.9	2.9	2.6	2.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Spruce	5.6	5.6	7.0	7.0	6.1	6.1	4.8	4.8	3.3	3.3	2.0	2.0	2.0	2.0	2.0
Other conifers	3.9	3.9	5.0	5.0	4.3	4.3	3.5	3.5	2.7	2.7	2.0	2.0	2.0	2.0	2.0
Oak	1.4	1.4	3.9	3.9	3.7	3.7	3.3	3.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Beech	1.7	1.7	7.1	7.1	6.4	6.4	5.5	5.5	4.1	4.1	2.8	2.8	2.8	2.8	2.8
Other hardwoods	1.6	1.6	5.5	5.5	5.1	5.1	4.4	4.4	3.0	3.0	2.4	2.4	2.4	2.4	2.4
Birch	2.9	2.9	3.8	3.8	3.1	3.1	2.4	2.4	1.6	1.6	0.9	0.9	0.9	0.9	0.9
Aspen	4.7	4.7	5.4	5.4	3.9	3.9	2.7	2.7	1.7	1.7	0.7	0.7	0.7	0.7	0.7
Alder	4.3	4.3	5.7	5.7	3.8	3.8	2.8	2.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0
Other softwoods	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Other tree species	*3.8*	*3.8*	*4.6*	*4.6*	*3.5*	*3.5*	*2.5*	*2.5*	*1.6*	*1.6*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Shrubs	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Carpathian Mts.															
Pine	2.9	2.9	4.4	4.4	4.6	4.6	3.7	3.7	3.0	3.0	1.7	1.7	1.7	1.7	1.7
Spruce	5.8	5.8	7.3	7.3	6.4	6.4	5.0	5.0	3.6	3.6	2.2	2.2	2.2	2.2	2.2
Other conifers	4.3	4.3	5.8	5.8	5.5	5.5	4.3	4.3	3.3	3.3	1.9	1.9	1.9	1.9	1.9
Oak	2.9	2.9	4.8	4.8	4.7	4.7	3.7	3.7	2.9	2.9	2.1	2.1	2.1	2.1	2.1
Beech	1.7	1.7	7.1	7.1	6.4	6.4	5.5	5.5	4.1	4.1	2.8	2.8	2.8	2.8	2.8
Other hardwoods	2.5	2.5	5.5	5.5	5.2	5.2	4.3	4.3	3.3	3.3	2.3	2.3	2.3	2.3	2.3
Birch	2.9	2.9	3.8	3.8	3.1	3.1	2.4	2.4	1.6	1.6	0.9	0.9	0.9	0.9	0.9
Aspen	4.7	4.7	5.4	5.4	3.9	3.9	2.7	2.7	1.7	1.7	0.7	0.7	0.7	0.7	0.7
Alder	4.3	4.3	5.7	5.7	3.8	3.8	2.8	2.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0
Other softwoods	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Other tree species	*3.8*	*3.8*	*4.6*	*4.6*	*3.5*	*3.5*	*2.5*	*2.5*	*1.6*	*1.6*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Shrubs	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Crimean Mts.															
Pine	2.1	2.1	2.9	2.9	2.6	2.6	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Spruce	5.5	5.5	6.9	6.9	6.0	6.0	4.7	4.7	3.2	3.2	2.0	2.0	2.0	2.0	2.0
Other conifers	3.8	3.8	4.9	4.9	4.3	4.3	3.4	3.4	2.6	2.6	2.0	2.0	2.0	2.0	2.0
Oak	1.4	1.4	3.9	3.9	3.7	3.7	3.3	3.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Beech	1.7	1.7	7.1	7.1	6.4	6.4	5.5	5.5	4.1	4.1	2.8	2.8	2.8	2.8	2.8

	Age														
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-999
Other hardwoods	1.5	1.5	5.4	5.4	5.0	5.0	4.3	4.3	3.0	3.0	2.3	2.3	2.3	2.3	2.3
Birch	2.9	2.9	3.8	3.8	3.1	3.1	2.4	2.4	1.6	1.6	0.9	0.9	0.9	0.9	0.9
Aspen	4.7	4.7	5.4	5.4	3.9	3.9	2.7	2.7	1.7	1.7	0.7	0.7	0.7	0.7	0.7
Alder	4.3	4.3	5.7	5.7	3.8	3.8	2.8	2.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0
Other softwoods	3.8	3.8	4.6	4.6	3.5	3.5	2.5	2.5	1.6	1.6	0.8	0.8	0.8	0.8	0.8
Other tree species	*3.8*	*3.8*	*4.6*	*4.6*	*3.5*	*3.5*	*2.5*	*2.5*	*1.6*	*1.6*	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Shrubs	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*

Carbon stock losses were calculated as the sum of losses from harvesting and other losses (equation 2.11 of the 2006 IPCC Guidelines).

GHG emissions from biomass losses reported in CRF Table 4.A include:

- GHG emissions from losses of above-ground biomass from all types of harvesting (excluding wood included into HWP estimations in order to avoid double counting);
- GHG emissions from below-ground biomass losses from all types of harvesting;
- GHG emissions from losses of above-ground and below-ground biomass from disturbances (not including forest fires);
- GHG emissions from below-ground biomass losses from forest fires (emissions from aboveground biomass burning are reported under biomass burning in CRF Table 4(V)).

Data on the amount of annual carbon losses at harvesting were calculated according to equation 2.12 from 2006 IPCC Guidelines.

To estimate the amount of biomass at harvesting, information about logging in forests of Ukraine was used. This information for the period of 1990-2021 was obtained based on data of the State Statistics Service of Ukraine and the State Forest Resources Agency of Ukraine (Table A3.3.5).

Table A3.3.5. Harvesting volumes of timber (total stock), thousand m^3

Year	Harvesting volumes, thousand m^3
1990	14127.8
1991	12061.0
1992	12514.2
1993	12497.2
1994	11782.5
1995	11651.3
1996	13782.0
1997	13546.7
1998	11521.1
1999	11244.2
2000	12735.9
2001	13365.4
2002	14692.1
2003	15953.3
2004	17300.7
2005	17124.3
2006	17759.8
2007	19013.9
2008	17687.5
2009	15876.5
2010	18064.6
2011	19746.2
2012	19763.6
2013	20340.6
2014*	20751.5
2015*	22107.9
2016*	22834.6
2017*	22151.2
2018*	22749.2
2019*	21046.5
2020*	17990.0
2021*	17859.3
*Data of the State Statistic Service of Ukraine, corrected using analytical study [6]	

The statistics presented in the total amount of harvested wood. In the 2006 IPCC Guidelines, equation 2.12 implies introduction of biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark) - $BCEF_R$. For a number of species (namely - conifers and hardwoods, as indicated in Table 4.5), default factors were used. For softwood species, due to lack of default values, the method of use of biomass expansion factors and wood density was applied (introduced in GHG LULUCF and also available as additional method in 2006 IPCC Guidelines, below equation 2.12). Table A3.3.6 presents factors for specific species. According to the IPCC, $BCEF_R$ for softwood species was estimated as the ratio of the biomass expansion factor BEF_2 and wood density D. The result of such an assessment is also listed in Table A3.3.6.

Moreover, Table A3.3.6 shows average ratios of below-ground to above-ground biomass. Selection of the $BCEF_R$ factor was justified by the average stand stock in Ukraine in the relevant year. Table A3.3.5 presents values for 2015. It should be noted that apart from hardwood species, for other species this indicator has the same value throughout the time series. Because hardwood species in 1995 had the average stock less than 200 m^3/ha, the corresponding $BCEF_R$ factor was used (1.17, according to the IPCC, Table 4.5).

Table A3.3.6. Factors used at estimation of GHG emissions from biomass loss

	Conversion factor for the entire above-ground biomass by harvesting above-ground biomass $BCEF_R$	Ratio of below-ground to above-ground biomass R	Biomass expansion factor BEF_2	Density, D
Pine (Pinus)	0.77	0.16	NA	NA
Spruce (Picea)	0.77	0.14	NA	NA
Fir (Abies)	0.77	0.14	NA	NA
Other conifers	0.77	0.14	NA	NA
Oak (Quercus)	0.89	0.16	NA	NA
Beech (Fagus)	0.89	0.15	NA	NA
Ash (Fraxinus)	0.89	0.15	NA	NA
Hornbeam (Carpinus)	0.89	0.15	NA	NA
Other hardwood	0.89	0.15	NA	NA
Birch (Betula)	0.437	0.12	1.15	0.38
Aspen (Populus)	0.4025	0.12	1.15	0.35
Alder (Alnus)	0.4025	0.12	1.15	0.35
Other softwood	0.4025	0.12	1.15	0.35

GHG emissions from disturbances were estimated using equation 2.14 of the 2006 IPCC Guidelines, however it was modified for a more accurate account of national circumstances. In particular, the rate of the average amount of above-ground biomass (B_w) was replaced with the average growing stock, which with the factors from Table A3.3.6 was converted into dry matter.

Considering the proportion of biomass losses as a result of disturbances for 1990-2013 and 2018-2021, it was determined by introducing a correction factor. It was delivered by overlapping data on timber losses due to disturbances, collected by the State Statistic Service of Ukraine, and calculated data losses by multiplying areas of disturbances by average wood stock. Since data on actual wood loss was collected only for 2014-2017 years, correction factor based on comparison for these years was applied for the rest of years, when actual wood loss was unknown from official sources.

Factors for AR Crimea, Sevastopol city, Donetsk and Lugansk regions were accepted as 1.0 because activity data were adjusted to cover entire territory of Ukraine, not covered by official statistics.

For some particular years the correction factors are higher, than 1.0. This is seen as actual losses of wood per ha is higher than average wood stock per ha in that region. Taking into account, that it is common that middle-age and old stands are more frequently affected by disturbances, the factor higher than 1.0 is possible.

Correction factor of actual wood loss allows to allocate a portion of wood lost during the disturbance event. The rest of the wood may be harvested or left on the site depending on the character of disturbance and its severity. Since all harvested wood is reported by the State Statistic Service of Ukraine, harvested wood after disturbance is taken into account in living biomass C-losses.

If the wood is left on the site as living biomass, C-gains might be underestimated since the area is reported as reforested and thus C-gains are calculated based on 1-10 years old stand despite older trees have higher C-gains rates.

Standing or lying deadwood left on the area after disturbances is not taken into account until Tier 2 method is applied to DOM pool in Forest Land.

Table A3.3.7. Determination of the correction factor relative to actual losses of wood at disturbance events based on data for 2014-2017 years

Region	Estimated loss of wood with average values of growing stock, m^3		Actual losses of wood according to statistical reporting 3-LG*, m^3		Correction factor	
	Coniferous	Deciduous	Coniferous	Deciduous	Coniferous	Deciduous
2014						
Ukraine	3630989	560867	2774685	687080		
AR Crimea	0	0	4233	4246	1.00	1.00
Vinnytska	102170	13681	33773	5227	0.33	0.38
Volynska	285141	48476	151887	36164	0.53	0.75
Dnipropetrovska	2658	5813	1558	4468	0.59	0.77
Donetska	4889	8825	42369	76485	8.67	8.67
Zhytomyrska	355567	6778	246098	6267	0.69	0.92
Transcarpathian	598721	143109	518837	195002	0.87	1.36
Zaporizhska	39	770	41	784	1.06	1.02
Ivano-Frankivska	349391	5356	281079	6342	0.80	1.18
Kyivska	221	45	283	82	1.28	1.84
Kirovohradska	11796	88273	10699	91885	0.91	1.04
Luganska	47632	17609	145095	53641	3.05	3.05
Lvivska	237573	30342	120644	19896	0.51	0.66
Mykolaivska	2047	14177	1435	12913	0.70	0.91
Odesska	703	52025	1002	51526	1.43	0.99
Poltavska	0	0	0	0		
Rivnenska	565306	21187	361086	17218	0.64	0.81
Sumska	151998	11790	122626	13940	0.81	1.18
Ternopilska	11487	18201	7280	15014	0.63	0.82
Kharkivska	4763	902	2891	710	0.61	0.79
Khersonska	19751	7886	217	119	0.01	0.02
Khmelnytska	76119	17676	70595	23830	0.93	1.35
Cherkaska	151257	26774	112848	26492	0.75	0.99
Chernivetska	308745	16592	257308	18411	0.83	1.11
Chernihivska	318515	4582	257488	5524	0.81	1.21
Kyiv city	24501	0	22982	0	0.94	
Sevastopol	0	0	332	893	1.00	1.00
2015						
Ukraine	4371450	798548	3040252	832883		
AR Crimea	0	0	4634	5132	1.00	1.00
Vinnytska	22414	3212	18044	2793	0.81	0.87
Volynska	355033	57198	211620	50386	0.60	0.88
Dnipropetrovska	1506	2771	998	2860	0.66	1.03
Donetska	422	674	46385	92444	109.97	137.15
Zhytomyrska	458244	8604	287793	7329	0.63	0.85
Transcarpathian	680116	219726	619793	232946	0.91	1.06
Zaporizhska	55	640	55	1045	1.01	1.63
Ivano-Frankivska	367586	6403	294690	6649	0.80	1.04
Kyivska	76800	16050	25749	7498	0.34	0.47
Kirovohradska	16051	119302	16046	137804	1.00	1.16
Luganska	267497	90344	158848	64833	0.59	0.72
Lvivska	346527	51482	279631	46115	0.81	0.90
Mykolaivska	2403	25115	1855	16699	0.77	0.66
Odesska	1478	43188	910	46787	0.62	1.08
Poltavska	0	0	0	0		
Rivnenska	964929	35222	457292	21805	0.47	0.62
Sumska	63097	5397	78593	8934	1.25	1.66
Ternopilska	13324	20093	6393	13187	0.48	0.66
Kharkivska	0	0	0	0		
Khersonska	99589	43586	0	0	0.00	0.00
Khmelnytska	42786	8882	84222	28429	1.97	3.20
Cherkaska	149836	25551	97965	22999	0.65	0.90
Chernivetska	194291	11122	161888	11584	0.83	1.04
Chernihivska	217142	3985	165345	3547	0.76	0.89
Kyiv city	30324	0	21140	0	0.70	
Sevastopol	0	0	363	1079	1.00	1.00
2016						

Region	Estimated loss of wood with average values of growing stock, m^3		Actual losses of wood according to statistical reporting 3-LG*, m^3		Correction factor	
	Coniferous	Deciduous	Coniferous	Deciduous	Coniferous	Deciduous
Ukraine	4182795	619240	3351330	685789		
AR Crimea	0	0	5086	4188	1.00	1.00
Vinnytska	8400	1207	5916	915	0.70	0.76
Volynska	470873	76029	265327	63173	0.56	0.83
Dnipropetrovska	8342	15986	3334	9558	0.40	0.60
Donetska	1706	2821	50901	75447	29.84	26.75
Zhytomyrska	556037	10469	367150	9350	0.66	0.89
Transcarpathian	655524	211051	606784	228057	0.93	1.08
Zaporizhska	0	0	0	0		
Ivano-Frankivska	271563	4823	221442	4997	0.82	1.04
Kyivska	14217	2963	5523	1608	0.39	0.54
Kirovohradska	650	4817	375	3225	0.58	0.67
Luganska	32143	11351	174314	52913	5.42	4.66
Lvivska	284707	43438	237641	39190	0.83	0.90
Mykolaivska	1796	9946	1099	9887	0.61	0.99
Odesska	1307	86271	1240	63762	0.95	0.74
Poltavska	0	0	0	0		
Rivnenska	978442	35462	752344	35875	0.77	1.01
Sumska	91093	7594	72138	8201	0.79	1.08
Ternopilska	7708	12499	5437	11214	0.71	0.90
Kharkivska	0	0	0	0		
Khersonska	53330	18622	2327	1283	0.04	0.07
Khmelnytska	92933	22876	76948	25974	0.83	1.14
Cherkaska	141568	26625	93859	22035	0.66	0.83
Chernivetska	147394	9173	108557	7768	0.74	0.85
Chernihivska	363064	5214	293188	6290	0.81	1.21
Kyiv city	0	0	0	0		
Sevastopol	0	0	399	881	1.00	1.00
2017						
Ukraine	2430133	440791	1857200	515063		
AR Crimea	0	0	3165	14691	1.00	1.00
Vinnytska	4994	718	4785	741	0.96	1.03
Volynska	611952	98809	437260	104109	0.71	1.05
Dnipropetrovska	463	888	453	1299	0.98	1.46
Donetska	14997	24801	31679	64946	2.11	2.62
Zhytomyrska	191485	3605	118732	3024	0.62	0.84
Transcarpathian	300094	96618	248345	93339	0.83	0.97
Zaporizhska	0	0	0	0		
Ivano-Frankivska	52085	925	46276	1044	0.89	1.13
Kyivska	261631	54537	175882	51219	0.67	0.94
Kirovohradska	1903	14108	2379	20435	1.25	1.45
Luganska	45210	15966	108487	45548	2.40	2.85
Lvivska	172400	26304	106354	17539	0.62	0.67
Mykolaivska	198	1097	197	1769	0.99	1.61
Odesska	599	39523	956	49153	1.60	1.24
Poltavska	0	0	0	0		
Rivnenska	555615	20137	451104	21510	0.81	1.07
Sumska	1681	140	1734	197	1.03	1.41
Ternopilska	90	145	156	323	1.75	2.22
Kharkivska	0	0	0	0		
Khersonska	47577	16614	0	0	0.00	0.00
Khmelnytska	69472	17101	47078	15891	0.68	0.93
Cherkaska	40347	7588	27072	6355	0.67	0.84
Chernivetska	9883	615	7512	537	0.76	0.87
Chernihivska	38576	554	29618	635	0.77	1.15
Kyiv city	8882	0	7729	0	0.87	
Sevastopol	0	0	248	758	1.00	1.00
Average						
Ukraine	-	-	-	-	-	-
AR Crimea	-	-	-	-	1.00	1.00
Vinnytska	-	-	-	-	0.70	0.76
Volynska	-	-	-	-	0.60	0.88
Dnipropetrovska	-	-	-	-	0.66	0.97
Donetska	-	-	-	-	1.00	1.00
Zhytomyrska	-	-	-	-	0.65	0.88

Region	Estimated loss of wood with average values of growing stock, m^3		Actual losses of wood according to statistical reporting 3-LG*, m^3		Correction factor	
	Coniferous	Deciduous	Coniferous	Deciduous	Coniferous	Deciduous
Transcarpathian	-	-	-	-	0.88	1.12
Zaporizhska	-	-	-	-	1.03	1.33
Ivano-Frankivska	-	-	-	-	0.83	1.10
Kyivska	-	-	-	-	0.67	0.95
Kirovohradska	-	-	-	-	0.93	1.08
Luganska	-	-	-	-	1.00	1.00
Lvivska	-	-	-	-	0.69	0.78
Mykolaivska	-	-	-	-	0.77	1.05
Odesska	-	-	-	-	1.15	1.01
Poltavska	-	-	-	-	1.00	1.00
Rivnenska	-	-	-	-	0.67	0.88
Sumska	-	-	-	-	0.97	1.33
Ternopilska	-	-	-	-	0.89	1.15
Kharkivska	-	-	-	-	0.61	0.79
Khersonska	-	-	-	-	0.01	0.02
Khmelnytska	-	-	-	-	1.10	1.65
Cherkaska	-	-	-	-	0.68	0.89
Chernivetska	-	-	-	-	0.79	0.97
Chernihivska	-	-	-	-	0.79	1.11
Kyiv city	-	-	-	-	0.84	1.00
Sevastopol	-	-	-	-	1.00	1.00

*statistical form data were adjusted for Crimea and the city of Sevastopol, Donestk and Lugansk regions

Table A3.3.8. Average stock of forest stands in forests of the State Forest Resources Agency of Ukraine, m^3/ha

Region	1995			2001			2007			2008			2009		
	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood
Ukraine, in average	**239**	**196**	**156**	**262**	**214**	**167**	**277**	**222**	**173**	**279**	**230**	**171**	**278**	**226**	**169**
AR Crimea	126	147	219	143	150	225	165	156	240	168	158	243	173	159	246
Vinnytska	220	203	211	229	216	188	256	227	200	257	229	205	262	231	205
Volynska	205	162	142	230	176	150	244	187	149	248	190	151	252	193	153
Dniprope-trovska	131	115	198	161	133	219	190	149	232	195	152	236	202	155	239
Donetska	186	135	211	184	147	209	206	152	188	211	151	190	214	154	192
Zhytomyrska	222	181	161	245	213	172	268	224	180	261	227	162	262	228	163
Transcarpa-thian	415	312	194	399	330	188	418	345	177	421	346	181	427	350	186
Zaporizhska	73	73	182	90	75	211	122	89	248	97	71	169	101	70	171
Ivano-Frank-ivska	259	196	144	306	237	161	325	255	180	322	236	189	303	245	162
Kyivska	254	198	154	279	211	170	294	218	174	292	220	175	295	221	177
Kirovohradska	183	188	185	183	190	167	196	187	182	188	181	161	192	183	163
Luganska	182	119	160	208	132	177	216	126	172	220	133	162	223	132	161
Lvivska	268	215	144	289	190	157	282	253	170	287	256	173	291	259	176
Mykolaivska	96	78	148	120	91	153	133	99	127	136	100	129	141	103	131
Odesska	61	142	155	68	143	175	93	142	186	98	145	186	102	147	190
Poltavska	248	176	177	256	192	191	272	206	197	271	200	191	279	207	187
Rivnenska	183	160	140	208	174	146	220	180	154	223	182	157	212	188	141
Sumska	301	219	163	331	236	185	336	258	192	348	261	194	347	265	200
Ternopilska	361	203	202	237	183	192	259	201	192	264	203	195	268	205	199
Kharkivska	247	186	185	270	203	193	289	218	213	291	220	216	295	223	221
Khersonska	86	104	193	109	111	211	127	75	131	130	76	133	135	77	135
Khmelnytska	242	189	177	266	199	182	292	210	196	296	212	196	299	214	198
Cherkaska	254	208	169	272	215	183	288	226	200	291	228	204	293	231	206
Chernivetska	345	230	202	341	269	189	350	282	204	350	284	209	353	287	212
Chernihivska	269	182	166	305	212	152	327	228	192	330	232	194	333	235	197
Kyiv city	254	198	154	279	211	170	294	218	174	292	220	175	295	221	177
Sevastopol	60	90	140	89	111	208	111	120	270	115	122	274	119	123	278

Region	2010			2011			2012			2013			2014		
	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood	Conifer-ous	Hard-wood	Soft-wood
Ukraine, in average	**274**	**223**	**162**	**277**	**228**	**171**	**277**	**230**	**171**	**279**	**229**	**172**	**280**	**231**	**174**
AR Crimea	190	166	255	182	162	252	173	158	212	173	158	212	182	161	217
Vinnytska	238	220	181	251	235	197	256	238	200	259	240	205	259	242	207
Volynska	240	193	148	260	198	159	241	198	147	246	201	150	250	204	153
Dniprope-trovska	216	161	230	215	161	245	220	164	249	226	149	200	234	152	205
Donetska	229	158	200	217	158	195	220	161	198	221	162	200	223	164	203
Zhytomyrska	257	224	155	268	232	167	271	233	168	271	235	171	272	236	171
Transcarpa-thian	381	318	117	398	342	154	403	346	159	406	349	163	408	352	167
Zaporizhska	106	72	176	112	75	179	118	76	183	125	77	187	130	79	191
Ivano-Frank-ivska	316	251	159	313	252	170	318	255	173	321	258	177	325	260	181
Kyivska	293	216	159	301	224	182	302	226	185	304	228	188	285	225	171
Kirovohradska	199	185	167	204	186	171	210	188	176	215	189	180	212	189	181
Luganska	223	134	164	217	135	161	220	138	164	222	140	166	225	143	168
Lvivska	277	247	146	282	262	171	285	265	174	288	268	177	290	270	180
Mykolaivska	146	105	136	150	108	138	152	109	143	119	73	113	125	75	118
Odesska	106	151	193	111	151	193	114	153	195	99	135	162	105	137	165
Poltavska	280	210	194	285	214	194	273	215	193	275	217	197	278	220	201
Rivnenska	210	184	138	219	194	147	222	196	150	224	198	153	226	200	156
Sumska	332	238	183	354	272	208	358	275	211	363	278	215	366	281	219
Ternopilska	234	202	161	274	210	204	278	211	206	258	208	194	265	210	196
Kharkivska	288	224	207	290	226	213	293	229	217	295	232	221	297	233	224
Khersonska	139	75	136	143	76	138	144	77	140	142	76	139	153	79	143
Khmelnytska	275	204	179	287	217	179	292	219	181	296	221	184	298	223	187
Cherkaska	292	231	209	298	235	213	301	237	216	277	229	190	282	231	194
Chernivetska	306	265	170	314	276	176	314	279	183	315	280	185	313	281	188
Chernihivska	325	228	192	313	232	185	318	235	188	322	238	192	326	241	197
Kyiv city	293	216	159	301	224	182	302	226	185	304	228	188	285	225	171
Sevastopol	123	124	280	120	122	279	124	124	263	124	124	263	133	127	270

Region	2015		2016		2017		2018		2019		2020	
	Coniferous	Decidu-ous	Coniferous	Deciduous	Coniferous	Deciduous	Coniferous	Deciduous	Coniferous	Deciduous	Coniferous	Deciduous
Ukraine, in av-erage	**281**	**219**	**284**	**224**	**280**	**220**	**279**	**223**	**277**	**222**	**276**	**222**
AR Crimea	168	154	174	160	173	153	172	158	171	158	173	158
Vinnytska	261	242	262	243	262	243	263	246	263	247	268	249
Volynska	252	170	252	171	255	172	258	175	260	177	263	180
Dniprope-trovska	253	162	256	171	267	168	276	176	278	176	282	178
Donetska	225	163	227	171	229	167	225	172	224	172	209	159
Zhytomyrska	275	203	278	205	278	206	252	186	252	186	255	189
Transcarpathian	410	352	418	358	396	336	397	339	396	338	358	329
Zaporizhska	137	84	145	92	146	87	149	90	156	92	133	73
Ivano-Frank-ivska	327	253	335	264	334	259	338	268	337	266	345	274
Kyivska	287	206	296	212	292	212	295	216	297	218	297	222
Kirovohradska	219	189	222	192	226	187	229	191	213	185	221	188
Luganska	232	146	230	152	225	151	227	155	225	156	202	150
Lvivska	287	258	287	265	286	265	290	268	291	268	293	271
Mykolaivska	101	118	132	81	124	109	139	83	142	85	146	88
Odesska	131	74	113	144	131	74	112	142	132	149	138	151
Poltavska	112	137	283	221	112	137	259	215	257	217	260	221
Rivnenska	280	214	229	174	253	210	230	175	208	155	209	155
Sumska	228	172	374	275	224	168	336	264	339	266	341	269
Ternopilska	368	269	274	216	331	260	278	219	281	221	286	224
Kharkivska	268	212	297	241	276	217	300	243	302	245	305	248
Khersonska	295	234	142	90	299	240	136	76	151	80	161	85
Khmelnytska	139	85	305	222	139	80	304	223	307	225	282	218
Cherkaska	299	217	291	233	302	221	296	237	300	239	303	242
Chernivetska	286	229	303	263	293	233	302	260	292	260	284	241
Chernihivska	308	264	331	222	300	259	332	227	333	229	334	230
Kyiv city	287	206	296	212	330	221	295	216	297	218	297	222
Sevastopol	168	154	124	125	173	153	124	124	119	124	124	124

The average stock of stem wood in forested forest land of the State Forest Resources Agency of Ukraine is presented in Table A3.3.8. It should be noted that before 2007 the average stock was determined with the same frequency as the forest inventory was held. To obtain the data for the other years, the methods of interpolation and extrapolation were used.

The data on average stock of forest stands in different regions for 2021 is usually obtained from the forest database of Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt". Because it is located in Irpin that was occupied in early days of the war in Ukraine in 2022, for the calculations the values from 2020 were used.

Emissions from above-ground biomass due to fires are not included into 4.A CSC in Forest Land CRF reporting table and were reported separately in the CRF reporting Table 4(V).

Forest fires in Ukraine traditionally are divided into 3 groups according to burnt biomass:

- Surface fires - only the litter burns, wood is not damaged or slightly damaged;
- Crown fires - litter and wood burn;
- Underground fires - the organic matter (peat) burns.

Data on fires are provided by the State Statistical Service of Ukraine in statistical form 3-lg. Information on fires for years 1990-2021 is presented in Table A3.3.9. It should be noticed that for the years 2014-2021 the data was corrected using analytical study.

Since 2018, the State Statistical Service of Ukraine stopped to collect data on forest fires. Thus, the data on areas of forest fires were obtained from the State Forestry Agency of Ukraine. Because the areas of forest fires, collected by the State Forestry Agency of Ukraine does not cover entire forests of Ukraine, the data for 2018-2021 were adjusted using correction factor.

The correction factor was derived by overlapping the data for 2016 and 2017 from the State Forestry Agency of Ukraine to the State Statistical Service of Ukraine and. In some regions this overlapping resulted in an outliers: some were below zero (areas from the State Forestry Agency of Ukraine was higher than from all of the forests), some were way above 1 (5 and more). Thus, for the adjustment average values for entire Ukraine was used, particularly:

- Surface fires – 1.11;
- Crown fires – 1.11.

The data on burnt and damaged wood were calculated based on area of crown fires and average stock per hectare, contained in table A3.3.8.

Table A3.3.9. Area covered by forest fires and completely burned harvested forest products

Year	Area covered by forest fires, ha			Burnt and damaged standing timber, m^3	Burnt and damaged harvested wood products, m^3
	Surface	Crown	Underground		
1990	1375	1012	1	79236	673
1991	1042	665	10	38051	241
1992	3318	672	111	77758	241
1993	2415	712	51	174354	155
1994	6071	3432	537	391159	840
1995	2095	1416	26	145400	2247
1996	7163	5466	42	308543	4169
1997	1355	110	2	11806	44
1998	3208	1208	2	123034	326
1999	2896	2632	14	163858	2863
2000	1386	222	2	20249	398
2001	1992	1770	3	139604	955
2002	4245	657	64	59206	417
2003	2406	359	49	19720	351
2004	536	37	1	1944	28
2005	2006	294	9	32101	90
2006	3729	557	1	53119	7039
2007	6238	7549		1304271	3952
2008	4218	1311		395257	7572
2009	5300	1010	5	223764	2832
2010	2697	966	5	343840	677

Year	Area covered by forest fires, ha			Burnt and damaged standing timber, m^3	Burnt and damaged harvested wood products, m^3
	Surface	Crown	Underground		
2011	979	70		11804	2405
2012	1611	1866	2	289291	999
2013	409	8	1	2496	1340
2014	12897	912	4	144975	1265
2015	14471	354	27	170967	10387
2016	1789	166	0	32840	257
2017	4830	1128	0	150056	82
2018	1238	301	0	24774	-
2019	1143	60	0	8918	-
2020	60941	21949	0	2849896	-
2021	337	4	0	478	

To estimate carbon emissions from fires, equation 2.14 of 2006 IPCC Guidelines was adapted to the above-mentioned classification (table A3.3.9). Accordingly, the emissions were estimated using the following method:

$$L_{fires} = (L_{surface} + L_{crown} + L_{underground} + L_{harvested}) \times G_{ef} \times 10^{-6} \qquad (A3.3.1)$$

где L_{fires} – total emissions from fires, kt C;
$L_{surface}$ – biomass losses from surface fires, t d.m.;
L_{crown} – biomass losses from crown fires, t d.m.;
$L_{underground}$ – biomass losses from underground fires, t d.m.;
$L_{harvested}$ – losses of harvested wood products, t d.m;
G_{ef} – EFs of gasses, kg/ t d.m.

Each component of equation A3.3.1 was respectively defined as:

$$L_{surface} = A_{surface} \times B_{litter} \times CF_{organic\ matter} \qquad (A3.3.2)$$

$$L_{crown} = A_{crown} \times B_{litter} \times CF_{organic\ matter} + \\ + W_{wood} \times BCEF_R \times (1 + R) \times C_f \times CF \qquad (A3.3.3)$$

$$L_{underground} = A_{underground} \times B_{organic\ matter} \times CF_{organic\ matter} \qquad (A3.3.4)$$

$$L_{harvested} = W_{harvested} \times D \times CF \qquad (A3.3.5)$$

where A is the area affected by fires: respectively, surface, crown, and underground ones, ha;
B_{litter} - litter stock burned in fire, t of d.s./ha;
$CF_{organic\ matter}$ - the fraction of carbon in litter and organic matter, t C/t d.m.;
W_{wood} - the amount of burnt and damaged wood, $m^{3;}$
$BCEF_R$ - coefficient accounting for the entire above-ground biomass by removed above-ground biomass, dimensionless;
R - the ratio of below-ground to above-ground biomass, dimensionless;
C_f - the fraction of biomass lost in fires, dimensionless;
CF - carbon content in dry matter of wood (the value by default is 0.47), t C/t d.m.;
$B_{organic\ matter}$ - the organic matter burned in fire, t d.m./ha;
$W_{harvested}$ - the amount of burnt harvested wood, $m^{3;}$
D - the average density of wood, t d.m./$m^{3.}$

According to national studies [12], the following values were applied: B_{litter} = 10 t/ha, $B_{organic\ matter}$ = 100 t/ha; $CF_{organic\ matter}$ = 0.37, f_d = 0.7, besides, the average value of D density values were determined based on density of individual species (listed in Table A3.3.6) and the ratio of coniferous/deciduous trees for particular years, as data on fires do not include a breakdown by species. The same $BSEF_R$ and R ratios were used as for biomass losses (see Table A3.3.6). G_{ef} coefficients were taken by default from Table 2.5 of 2006 IPCC.

During crown fires in forests, it is assumed that all biomass is lost – above- and below-ground. But with the aim to be consistent in reporting (GHG emissions from biomass losses – Table 4.A, emissions from actual burning – Table 4(V)), losses from below-ground biomass, above-ground part of which was burnt, were included in GHG emissions in Forest land table (CRF Table 4.A).

With the aim to assess below-ground losses from fires part of equation A3.3.3 on burnt wood estimation was used, but the ratios of below-ground to above-ground biomass were applied from Table A.3.3.4.

CO_2 emissions from liming on forest land were not calculated, since this type of activity is not performed in the forestry in Ukraine.

N_2O emissions from fertilizer application were not estimated due to lack of fertilizer application in forestry in Ukraine.

N_2O emissions from drainage of organic soils were calculated using the default coefficient [1] and are presented in CRF Table 5(II).

On the lands converted to forests, carbon emission/removal estimations in living biomass estimates were conducted similarly to estimations for sub-category 4.A.1, but with application of biomass growth rates for Land converted to forest land (Table A3.3.10).

Table A3.3.10. Biomass growth by natural zones and species for Land converted to forest land (national data), t/ha/yr

Natural zones and species	Increase in above-ground biomass	Ratio of below-ground and above-ground biomass growth	Aggregated value of the factors adopted for estimation
			Polissia
Pine	3.1	0.20	3.72
Spruce	4.8	0.30	6.24
Other conifers	3.4	0.20	4.08
Oak	2.5	0.25	3.13
Other hardwood	2.4	0.24	2.98
Birch	2.6	0.15	2.99
Alder	3.8	0.15	4.37
Aspen	4.2	0.15	4.83
Other softwood	4.0	0.15	4.60
Other tree species	3.4	0.15	3.91
			Forest Steppe
Pine	2.5	0.20	3.00
Spruce	4.4	0.30	5.72
Other conifers	3.4	0.20	4.08
Oak	2.6	0.25	3.25
Beech	1.6	0.22	1.95
Other hardwood	2.0	0.20	2.40
Birch	2.6	0.20	3.12
Alder	3.8	0.20	4.56
Aspen	4.2	0.20	5.04
Other softwood	4.0	0.20	4.80
Other tree species	3.4	0.20	4.08
			North Steppe
Pine	2.0	0.22	2.44
Oak	1.4	0.27	1.78
Other hardwood	1.5	0.25	1.88
Birch	2.5	0.21	3.03
Alder	3.6	0.21	4.36
Aspen	4.0	0.21	4.84
Other softwood	3.8	0.20	4.56
Other tree species	3.2	0.20	3.84
			South Steppe
Pine	1.6	0.22	1.95
Oak	1.2	0.28	1.54
Other hardwood	1.4	0.25	1.75
Birch	2.4	0.20	2.88

Natural zones and species	Increase in above-ground biomass	Ratio of below-ground and above-ground biomass growth	Aggregated value of the factors adopted for estimation
Alder	3.5	0.20	4.20
Other softwood	3.6	0.20	4.32
Other tree species	3.2	0.20	3.84
			Carpathian Mts.
Pine	2.4	0.20	2.88
Spruce	5.0	0.30	6.50
Other conifers	4.8	0.20	5.76
Oak	1.6	0.25	2.00
Beech	1.8	0.22	2.20
Other hardwood	1.5	0.20	1.80
Birch	2.6	0.20	3.12
Alder	3.8	0.20	4.56
Aspen	4.2	0.20	5.04
Other softwood	4.0	0.20	4.80
Other tree species	3.4	0.20	4.08
			Crimean Mts.
Pine	1.6	0.20	1.92
Oak	1.4	0.26	1.76
Beech	1.5	0.24	1.86
Other hardwood	1.6	0.24	1.98
Aspen	3.2	0.20	3.84
Other softwood	2.8	0.20	3.36
Other tree species	2.6	0.20	3.12
Shrubs (all zones)	0.4	0.20	0.5

Annual changes in carbon stocks in dead organic matter pool were calculated using Tier 1 method and default EFs. Until new approach for DOM CSC estimations will be delivered it is assumed to have Carbon balance in DOM pool for Forest land remaining Forest land. For Land converted to Forest land equation 2.23 of IPCC 2006 was used with default EFs (table 2.2). This approach was used consistently for entire time series for any conversions to and from Forest land.

Estimation of carbon stock changes in soils for forest land remaining forest land was not performed, since national studies confirm stable carbon stocks in forest soils [4]. It was also assumed that after a period of conversion from sub-category 4.A.2 to 4.A.1, in those areas a stable stock of carbon in soil is formed as well, so the carbon balance was also taken to be zero.

Estimation of carbon stock change in SOM pool of Land converted to forest land was held under Tier 1 with application of default factors. Ukraine made an estimation of soils based on data from Harmonized World Soil Database v.1.2 for use of Table 2.3 of 2006 IPCC guidelines. The exact soil types were selected as included into description of Table 2.3 of IPCC 2006. The following results were observed.

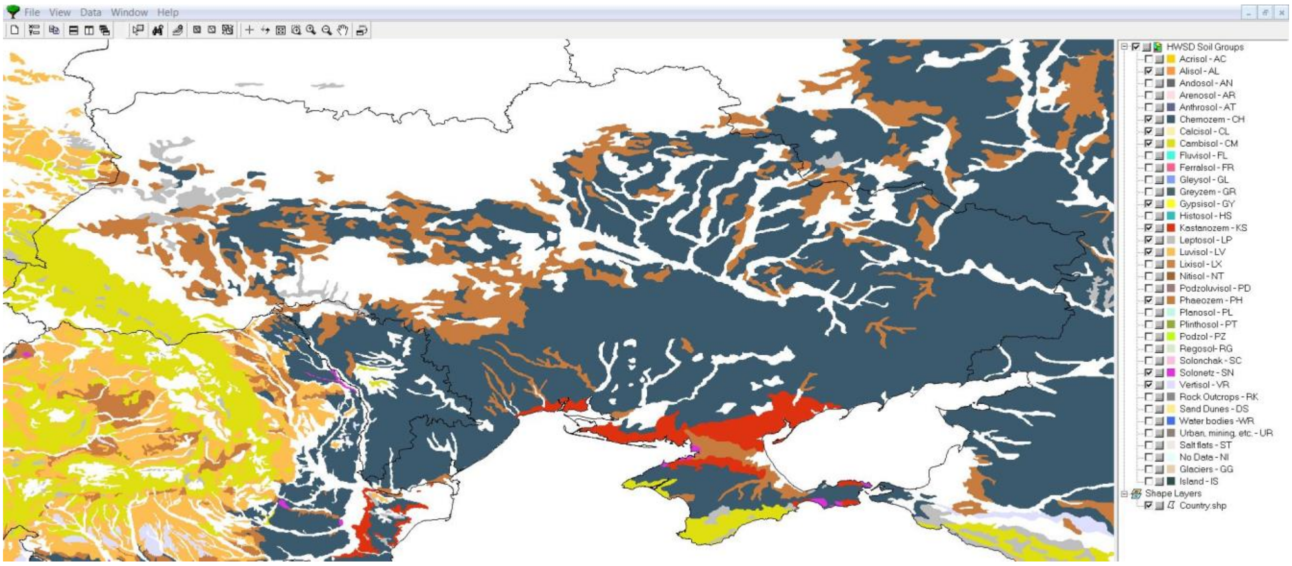

Fig. A3.3.1. HAC soils

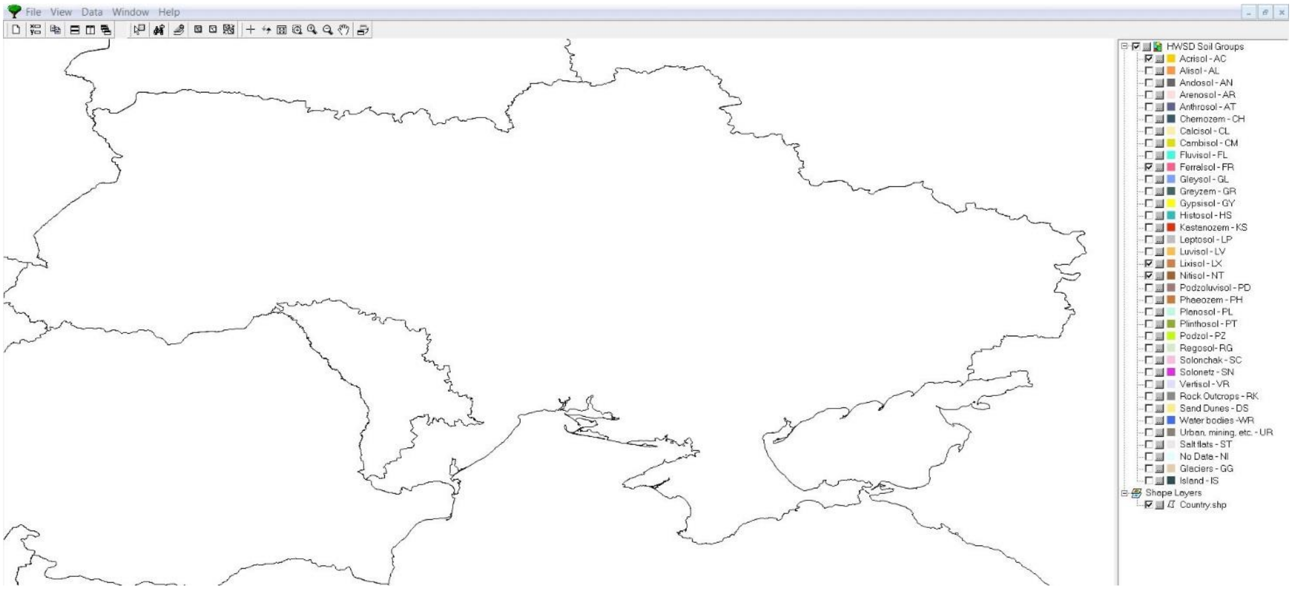

Fig. A3.3.2. LAC soils

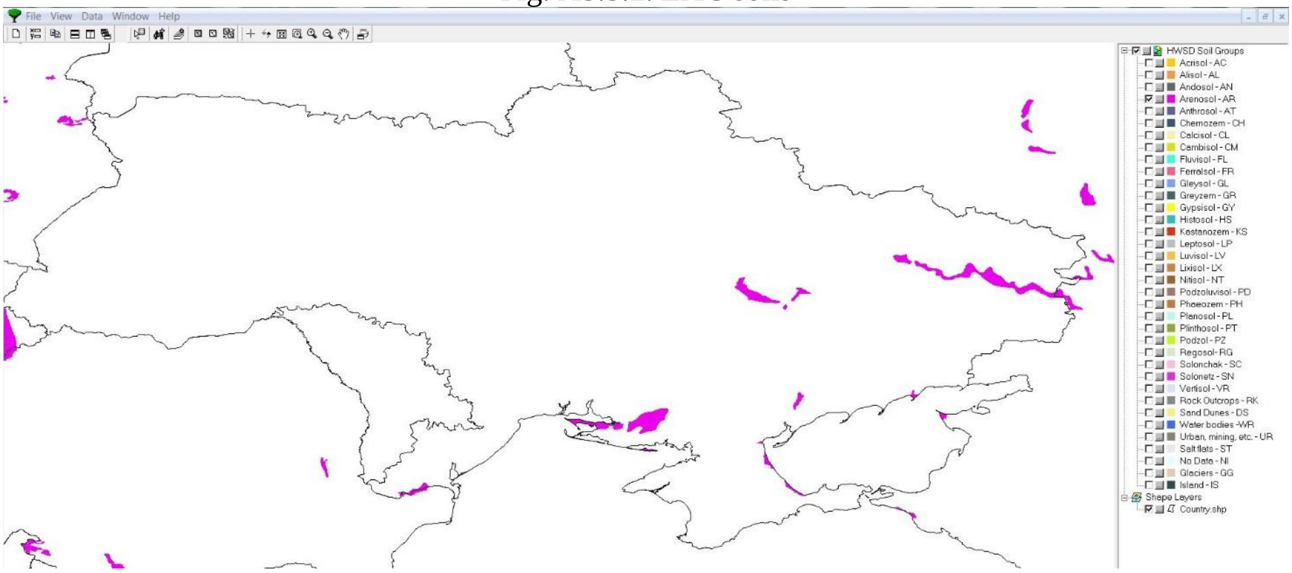

Fig. A3.3.3. Sandy soils

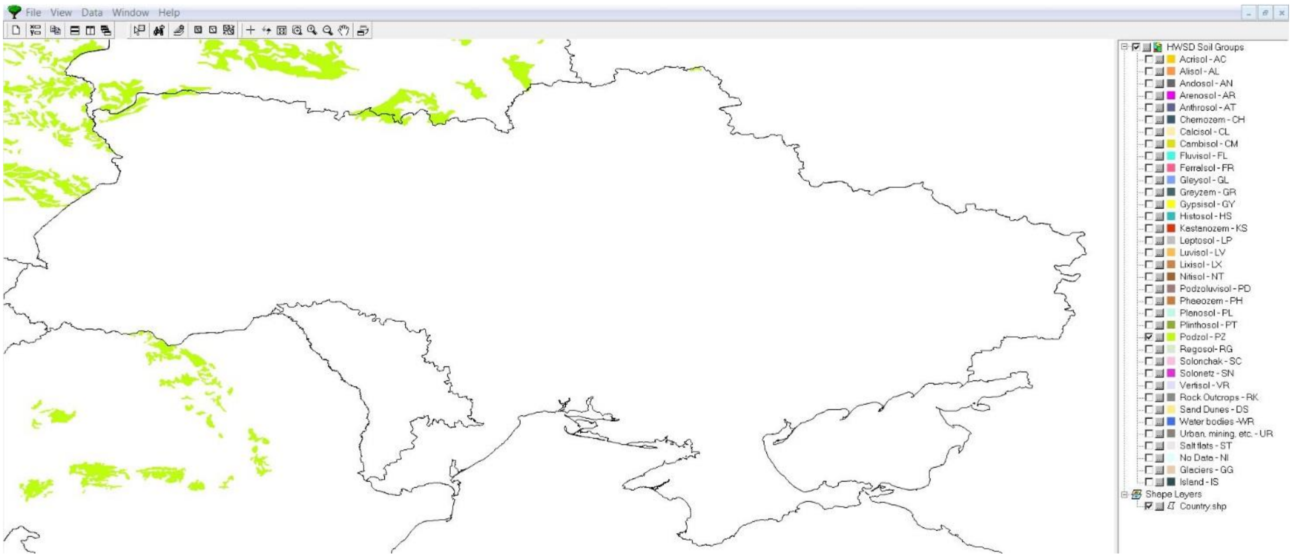

Fig. A3.3.4. Spodic soils

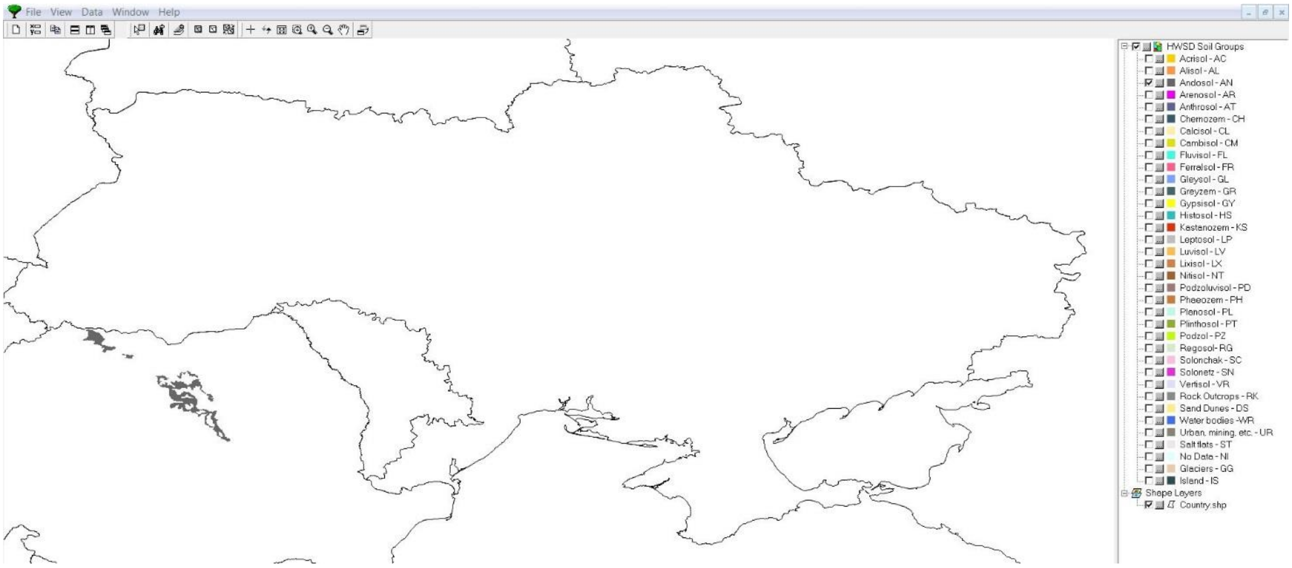

Fig. A3.3.5. Volcanic soils

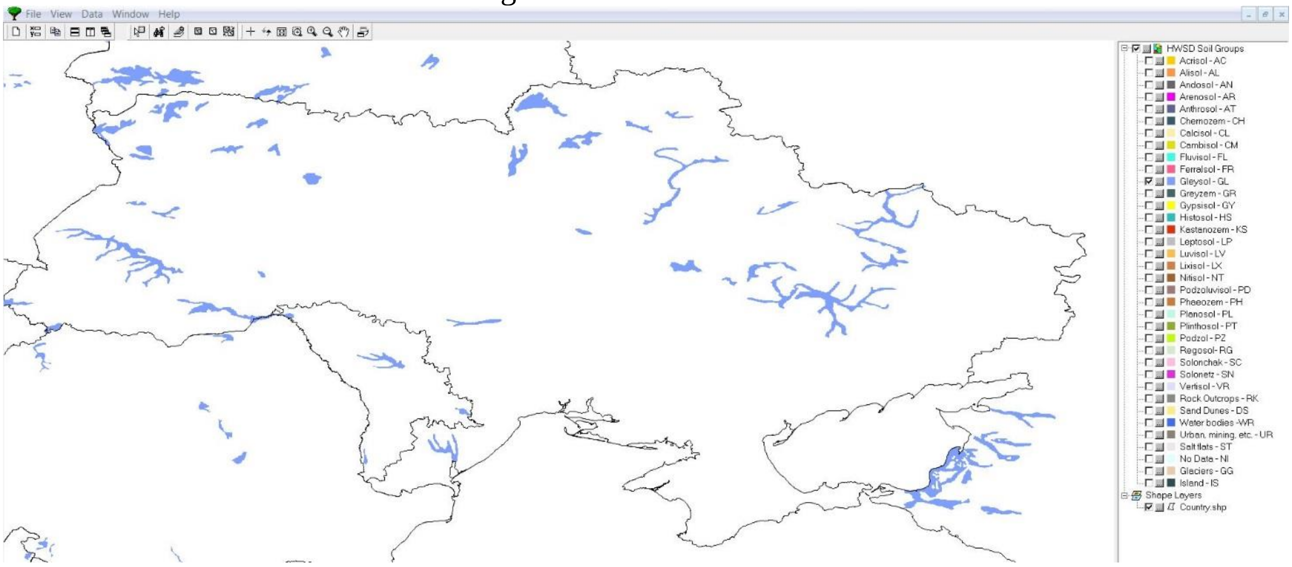

Fig. A3.3.6. Wetlands soils

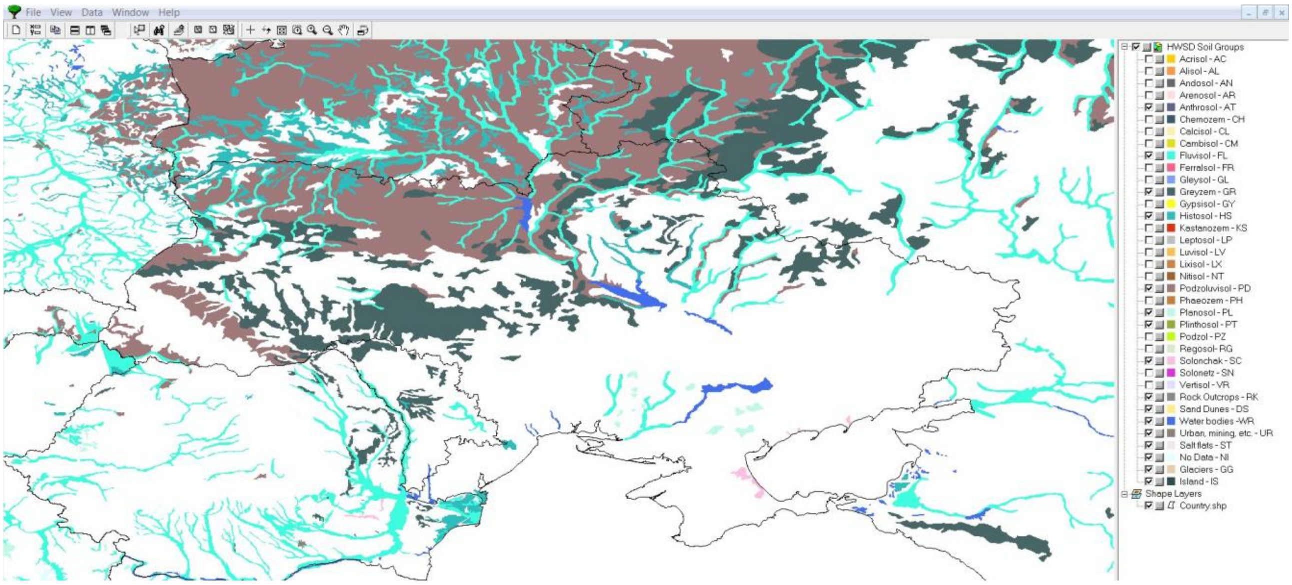

Fig. A3.3.7. Unclassified soils

Among soils, not classified clearly by IPCC:

a) Anthrosol – absent in Ukraine;

b) Fluvisol – in Ukraine clearly common alongside rivers. According to the HWSD, sand content is 80 %, clay is 8 %, so it's a sandy soil, in accordance with guidance from fig. 3A.5.3 of IPCC 2006.
c) Greyzem – in the current FAO classification it is included into Phaeozems, which are HAC soils;
d) Histosols – organic soils;
e) Podzoluvisols – in the current FAO classification included into Albeluvisols, which are HAC soils;
f) Planosols – low sand content (14 %) and high clay content (41 %) in 0-30 cm layer. Literature sources indicates its low C-content, thus potentially SOCref for this soil might be taken as for LAC soils;
g) Plinthosols – absent in Ukraine;
h) Solonchak – commonly grouped with Solonetz soils, it is expected to be included into the same group of soils by C content in 30 cm layer (HAC soils).

So, potentially only Planosols could be LAC soils.

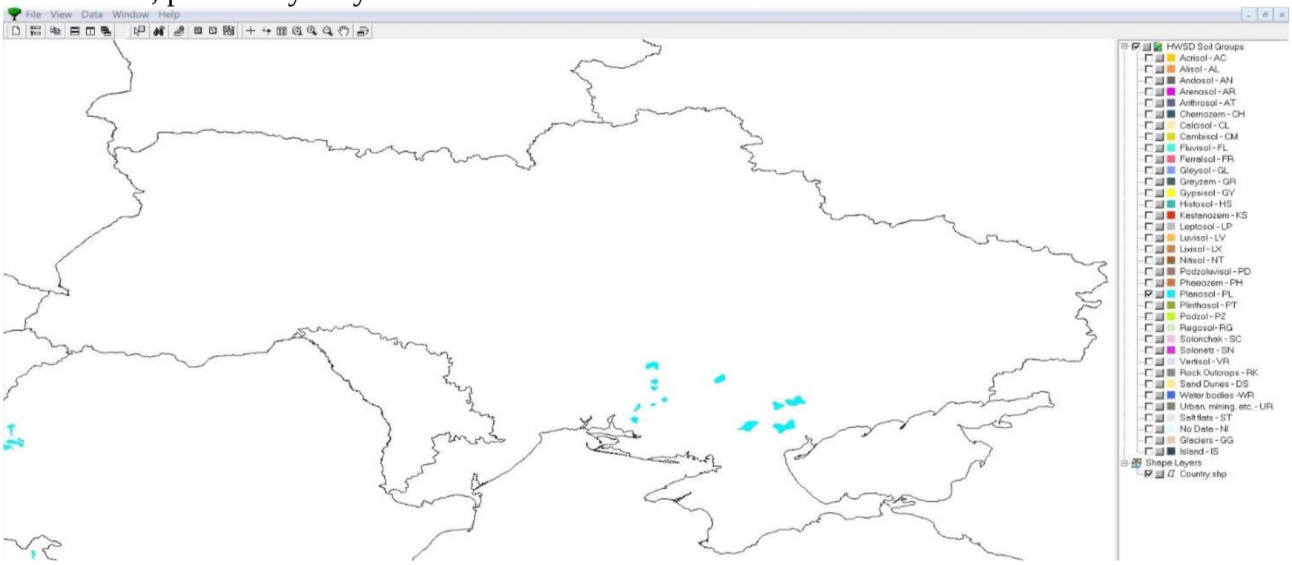

Fig. A3.3.8. Planosols

Based on that, the absolute majority of mineral soils in Ukraine are HAC soils. Thus, conservatively all conversions between land-use categories consider to occur on HAC soils.

Direct and indirect nitrogen emissions from mineralization from land conversion to forest land emissions were estimated using the Tier 1 method (equations 11.1 and 11.8 of the 2006 IPCC Guidelines). However due to Carbon stock gains on lands converted to Forest Land, these emissions do not occur.

A3.3.2 Methodological issues for the land-use categories Cropland and Grassland

Information on areas in the Cropland category was taken from statistical reporting form 16-zem, and from the land-use change matrix (Table 6.4) the areas of land converted to cropland were used.

To determine carbon stock changes in living biomass, the area of perennial fruit trees from form 16-zem and default EFs were used [1]. In Ukrainian statistics, there are no data on the dynamics of the areas of orchards, 6-zem form provides total area only.

To perform calculations of CSC the total area of orchards of 1990 was divided equally by default 30-year living cycle according to 2006 IPCC (see table A3.3.11). Any changes in the total area from 16-zem form was interpret as increase or decrease of planting of perennial woody vegetation, resulting in corresponding increase or decrease of 1-year old area of plants.

To calculate losses 30-year-old vegetation area was used as well as default carbon stock from Table 5.1 of Chapter 4 Volume 4 of 2006 IPCC Guidelines.

Table A3.3.11. Distribution of orchards areas by age and corresponding emissions, kha

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47
2	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97
3	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57
4	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37
5	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57
6	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22
7	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22
8	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32
9	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32
10	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27
11	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77
12	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47
13	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67
14	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37
15	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37
16	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
17	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
18	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
19	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
20	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
21	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
22	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
23	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
24	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
25	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
26	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
27	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
28	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
29	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
30	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37
Gains, kt C	1787.10	1768.20	1751.40	1764.63	1748.04	1715.28	1698.27	1656.17	1614.06	1596.95	1579.83	1567.65	1552.95	1542.87	1533.63	1529.64
Losses, kt C	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77	28.37	28.37	28.37	28.37	28.37	19.37
2	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77	28.37	28.37	28.37	28.37	28.37
3	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77	28.37	28.37	28.37	28.37
4	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77	28.37	28.37	28.37
5	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77	28.37	28.37
6	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77	28.37
7	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77	27.77
8	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07	28.77
9	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37	28.07
10	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57	28.37
11	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97	29.57
12	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57	27.97
13	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67	27.57
14	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67	28.67
15	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07	29.67
16	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47	26.07
17	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97	26.47
18	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57	23.97
19	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37	23.57
20	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57	21.37
21	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22	22.57
22	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22	20.22
23	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32	20.22
24	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32	8.32
25	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27	8.32
26	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77	20.27
27	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47	12.77
28	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67	20.47
29	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37	34.67
30	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	28.37	19.37	20.37
Gains. kt C	1524.81	1527.54	1528.17	1526.49	1525.65	1528.17	1528.17	1527.54	1528.38	1527.12	1527.12	1527.12	1527.12	1527.12	1527.12	1527.12
Losses. kt C	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1787.10	-1220.10	-1283.10

For estimation of carbon emissions in the pool of mineral soils, the nitrogen flow estimation balance method was used with subsequent recalculation for carbon.

The method is based on estimation of the balance between the amount of nitrogen outflow from soil, its removal from the field, and nitrogen inflow into the soil surface, taking into account the intensity and vectors of flows, its further movement. Removal of nitrogen from soil takes place with main products (harvest), side products, post-harvest crop residues, and plant roots. Inflow of nitrogen on the soil surface (or into the upper soil horizon) occurs with post-harvest crop residues, roots, organic and nitrogen mineral fertilizers, as a result of nitrogen fixation by legume crops, with precipitations.

Formation of the nitrogen balance indicating the link between the amount of carbon and nitrogen for agricultural land is explored in detail in national studies [16, 17, 18, 19] and originates from the soviet practice of the soil science [20-26]. Also, prior to application of this method for preparation of the GHG inventory for the pool of mineral soils in the land use Cropland category, it was presented at workshops [27, 28], and also was published [12, 29]. Before moving from application of IPCC Tier 2 methods to the national method of balance estimations, consultation with industry experts were held. The method was approved.

Thus, determination of the dynamics of nitrogen during agricultural land cultivation was held based on the following components of the credit and debit sides of balance estimations:

- components of the nitrogen debit part are soil inflows from:
  - humification of plant residues processes;
  - humification of organic fertilizers processes;
  - nitrogen-fixation by legumes;
  - precipitations;
- components of the credit part of the nitrogen are its removal with:
  - the yield of main products;
  - post-harvest crop residues;
  - by-products;
  - roots.

Besides, in the total amount of nitrogen removed with plants, it is necessary to determine the part that consumed by the plants due to humus mineralization processes. For this purpose, from the total nitrogen content in plants is reduced by the amount of nitrogen that entered the plant from:

- crop residues (above- and below-ground);
- organic fertilizers (the effect of leaching processes is taken into account);
- nitrogen mineral fertilizers (the effect of run-off processes is taken into account).

The amount of nitrogen that consumed by the plants due to processes of soil humus mineralization and led to carbon emissions into the atmosphere is estimated as the difference between the credit and debit sides of the balance calculation. If as a result of the estimations a value more than zero (>0) is obtained, it indicates accumulation of nitrogen and humus in soil, and, as a result, presence of carbon removal processes in mineral soils. In the NIR preparation, the described calculation scheme was applied taking into account the effect of climatic conditions and soil differences. This is because the intensity of the processes mentioned above is dependent on temperature conditions, humidity, soil texture, and other factors.

The values obtained for nitrogen credit and debit are converted into carbon volumes, equation A3.3.6:

$$\overline{C_r} = (\sum N_{D_i} + \sum N_j - \sum N_{M_{is}}) \times k_{C:N_s}, \tag{A3.3.6}$$

where $\overline{C_r}$ is the average annual carbon balance of soil humus, t/ha;
r - the index of the territory for which the estimation is performed;
N_{D_i} - the total amount of nitrogen released into the humus as a result of humification of dead organic matter (above- and below-ground) under crops grown for 2 years prior to the inventory, t/ha;
i - the type of crop;

N_j - the total amount of nitrogen released into the humus as a result of humification of organic fertilizers introduced into soil in the inventory year, t/ha;
j - the index of the type of organic fertilizer (manure bedding, liquid manure, poultry manure);
$N_{M_{is}}$ - the total amount of nitrogen in humus mineralized as a result of cultivation of crop i in the inventory year on soil s, t/ha;
s - the index of the soil type for which estimations were performed;
$k_{C:N_s}$ - carbon to nitrogen content ratio (C:N) in humic substances of ploughed layer.

To perform estimations based on data of the carbon in soil inventory, the assumption was made that humification processes take place one year after the harvest and introduction of the materials into the soil. Thus, the amounts of nitrogen input from crop residues, for example, for 1990, were calculated on the basis of data the harvest of 1988. The assumption makes it possible to more accurately take into account the features of the dynamics of nitrogen flows and does not introduce a substantial error into the calculations, because the increment adopted is covered by the estimation period (from 1990 to the inventory year).

The debit part of equation A3.3.6 is the sum of values of plant residue and organic fertilizer humification volumes.

The amount of nitrogen generated as a result of humification of the dead below- and above-ground organic matter (N_{D_i}) of agricultural crop biomass is estimated by multiplying the amount of biomass returned into soil after harvesting by the value of nitrogen content in it (taking into account direct emissions of nitrogen), and by humification factors, equation A3.3.7:

$$N_{D_i} = \sum_{Rs_i}[(B \times \eta - N_{CR}) \times k] + \sum_{Rt_i}[(B \times \eta - N_{CR}) \times k], \quad (A3.3.7)$$

where B is the amount of aboveground (Rs_i) and underground (Rs_i) crop residues, t/ha;
η - nitrogen content is aboveground (Rs_i) and underground (Rt_i) plant residues, relative units;
k - the factor of humification of above-ground (Rs_i) and below-ground (Rt_i) crop residues, relative units;
N_{CR} - the amount of nitrogen that is released annually as direct emissions from above-ground (Rs_i) and below-ground (Rt_i) plant residues, t/ha;
i - the crop index;

The amount of nitrogen coming from above- and below-ground plant residues is calculated on the basis of the linear regression equations [30], Table A3.3.12; their humification factors - Table A3.3.13 [17, 22], and their nitrogen content - Table A3.3.14 [23].

Table A3.3.12. Regression equation to determine the mass of crop residues based on the main product yield

Crop	Yield of the main products	Weight determination regression equation		
		for by-products	for above-ground residues	for roots
Winter rye	10-25 26-40	x=1.8y+3.8 x=1.0y+25	x=0.3y+3.2 x=0.2y+3.6	x=0.6y+8.9 x=0.6y+13.9
Winter wheat	10-25 26-40	x=1.7y+3.4 x=0.8y+25.9	x=0.4y+2.6 x=0.1y+8.9	x=0.9y+5.8 x=0.7y+10.2
Spring wheat	10-20 21-30	x=1.3y+4,2 x=0.5y+19,8	x=0.4y+1.8 x=0.2y+5.4	x=0.8y+6.5 x=0.8y+6.0
Barley	10-20 21-35	x=0.9y+6.5 x=0.9+7.2	x=0.4y+1.8 x=0.09y+7.6	x=0.8y+6.5 x=0.4y+13.4
Oats	10-20 21-35	x=1.5y-1.2 x=0.7y+16.2	x=0.3y+3,2 x=0.15y+6.1	x=1.0y+2 x=0.4y+16
Millet	5-20 21-30	x=1.5y+4.5 x=2.0y-7.1	x=0.2y+5 x=0.3y+3,3	x=0.8y+7 x=0.56y+11.2
Maize for grain	10-35	x=1.2y+17.5	x=0.23y+3.5	x=0.8y+5.8
Peas	5-20 21-30	x=1.3y+4,5 x=1.2y+3	x=0.14y+3.5 x=0.20y+1.7	x=0.66y+7.5 x=0.37y+12.9
Buckwheat	5-15 16-30	x=1.7y+4.7 x=1.3y+10,3	x=0.25y+4.3 x=0.2y+5.2	x=1.1y+5.3 x=0.54y+14.1
Sunflower	8-30	x=1.8y+5.3	x=0.4y+3.1	x=1.0y+6.6
Potato	50-200 201-350	x=0.12y+2 x=0.1y+3.9	x=0.04y+1 x=0.03y+4.1	x=0.08y+4 x=0.06y+8.6

Crop	Yield of the main products	Weight determination regression equation		
		for by-products	for above-ground residues	for roots
Sugar beet	100-200 201-400	x=0.14y-1.7 x=0.1y+10	x=0.02y+0.8 x=0.003y+2.3	x=0.07y+3.5 x=0.06y+5.4
Vegetables	50-200 250-400	x=0.12y+0.5 x=0.12y+0.0	x=0.02y+1.5 x=0.006y+3.6	x=0.06y+5 x=0.04y+6
Feed root crops	50-200 200-400	x=0.08y+0.1 x=0.11y-4.6	x=0.01y+1 x=0.003y+2.4	x=0.05y+5.5 x=0.05y+5.2
Flax	3-10	x=5y+15	-	x=1.3y+9,4
Hemp	3-10	x=5y+30	-	x=2.2y+9.1
Silage crops (without maize)	100-200	-	x=0.04y+4	x=0.09y=7
Maize for silage	100-200 201-350	- -	x=0.03y+3.6 x=0.02y+5	x=0.12y+8.7 x=0.08y+16.2
Annual grasses (vetch, peas, oats)	10-40	-	x=0.13y+6	x=0.7y+7.5
Perennial grasses	10-30 30-60	- -	x=0.2y+6 x=0.1y+10	x=0.8y+11 x=1y+15

Table A3.3.13. Humification and mineralization factors for crop residues in the ploughed layer of soil

Agricultural crop	Crop residue humification factors, relative units				Crop residue mineralization factors, t/ha		
	Polissia, Forest Steppe			Steppe	Polissia	Forest Steppe	Steppe
	humus <2.5%	humus >2.5%	humus >3.0%				
Winter wheat	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Spring wheat	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Winter rye	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Spring rye	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Winter barley	0.15	0.20	0.20	0.22	0.8	0.7	0.7
Spring barley	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Oats	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Millet	0.15	0.20	0.20	0.20	0.8	0.8	0.8
Buckwheat	0.15	0.20	0.20	0.20	0.8	0.8	0.8
Maize for grain	0.15	0.15	0.20	0.20	0.8	0.8	0.8
Rice	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Sorghum	0.15	0.20	0.20	0.20	0.8	0.8	0.8
Peas	0.15	0.20	0.21	0.23	0.8	0.7	0.7
Vetch	0.15	0.20	0.22	0.23	0.8	0.7	0.7
Annual grasses	0.15	0.20	0.20	0.23	0.8	0.7	0.7
Perennial grasses	0.20	0.20	0.23	0.23	0.8	0.7	0.7
Fodder beans for grain	0.20	0.20	0.23	0.23	0.8	0.7	0.7
Sugar beet	0.05	0.07	0.07	0.10	0.8	0.8	0.8
Potato	0.05	0.07	0.07	0.13	0.8	0.8	0.8
Vegetables	0.05	0.07	0.07	0.10	0.8	0.8	0.8
Fodder root crops	0.05	0.07	0.07	0.10	0.8	0.8	0.8
Food cucurbits	0.05	0.07	0.07	0.10	0.8	0.8	0.8
Fodder cucurbits	0.05	0.07	0.07	0.10	0.8	0.8	0.8
Sunflower	0.15	0.20	0.15	0.14	0.8	0.8	0.8
Long-stalked flax (fiber)	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Soybean	0.15	0.20	0.22	0.23	0.8	0.7	0.7
Hemp	0.15	0.20	0.20	0.20	0.8	0.7	0.7
Winter and spring rape	0.15	0.20	0.22	0.23	0.8	0.7	0.7
Maize for silage, green fodder, haylage	0.10	0.15	0.15	0.17	0.8	0.8	0.8

Table A3.3.14. Nitrogen content in crop plant residues, %

Crop	Above-ground residues	Roots
Winter rye	0.45	0.75
Winter wheat	0.45	0.75

Crop	Above-ground residues	Roots
Spring wheat	0.65	0.80
Barley	0.50	1.20
Oats	0.60	0.75
Millet	0.50	0.75
Buckwheat	0.80	0.85
Maize for grain	0.75	1.00
Sunflower	0.75	1.00
Peas, vetch	1.25	1.70
Flax	0.50	0.80
Hemp	0.25	0.50
Sugar beet	1.40	1.20
Fodder root crops	1.30	1.00
Potato	1.80	1.20
Vegetables	0.35	1.00
Silage crops (without corn)	1.00	1.10
Maize for silage	0.80	1.20
Annual grasses	1.10	1.20
Perennial grasses: - with clover	1.80	2.00
- with lucerne	2.00	2.20

Areas of crop harvest and yields, which are the AD for the calculations of volumes of crop residues (used in the calculation of N_{D_i}), as well as in the calculations of the amount of nitrogen in humus mineralized as a result of cultivation of crop i in the inventory year on soil s ($N_{M_{is}}$), are presented in the tables A3.3.15 and A3.3.16.

Table A3.3.15. The areas of crop harvest by main crop groups, thousand ha

	Grain (wheat, rye, barley etc.)	Pulses (beans, peas)	Industrial crops (sugar beet, flax, hemp etc.)	Oilseeds (sunflower, soybeans, rapeseeds)	Potato	Vegetables	Melons and gourds	Fodder crops	Grasses for hay and green mass	TOTAL
1990	13084.20	1405.20	1835.51	1821.18	1425.04	489.98	119.99	694.70	13417.39	34304.96
1991	13180.10	1352.80	1759.89	1757.18	1524.51	497.03	116.51	674.20	12892.86	33765.86
1992	12665.62	1289.99	1682.53	1783.83	1698.76	511.58	82.79	626.80	13256.22	33610.06
1993	12967.52	1229.69	1690.06	1739.57	1526.21	534.47	82.87	612.00	12627.03	33018.61
1994	12038.00	1183.10	1586.30	1792.68	1524.01	472.99	54.05	572.70	12981.10	32206.77
1995	12863.64	1076.21	1588.09	2082.46	1526.94	511.52	91.61	508.64	12074.99	32325.03
1996	11646.50	830.70	1352.69	2077.18	1545.55	464.61	79.54	427.50	11995.50	30419.85
1997	13811.40	690.94	1073.87	2048.25	1577.40	461.49	69.21	484.80	10623.40	30843.51
1998	12174.20	578.30	941.07	2563.69	1513.17	452.73	66.57	398.60	9965.10	28658.99
1999	11959.22	492.89	947.37	3091.12	1551.09	489.01	91.05	393.41	9257.58	28277.92
2000	12203.80	383.20	794.48	3084.86	1630.98	526.70	85.96	343.90	7722.60	26777.73
2001	14243.10	411.50	902.04	2596.91	1604.68	486.35	62.62	375.80	7154.00	27840.81
2002	13797.90	444.90	807.38	2943.23	1592.30	475.12	76.60	377.10	6440.70	26960.75
2003	10633.60	479.40	706.08	4204.03	1586.91	473.64	73.37	385.50	5737.20	24289.33
2004	14408.80	367.04	742.74	3986.50	1556.39	472.96	59.40	364.90	5017.30	26976.03
2005	14204.10	401.10	657.70	4412.92	1515.90	469.01	52.48	357.90	4716.40	26787.51
2006	13803.00	388.50	805.88	5106.71	1461.46	478.93	83.44	327.80	4171.90	26627.62
2007	13113.30	314.40	592.94	4847.88	1453.31	455.61	78.87	319.60	3946.90	25122.81
2008	15123.30	257.30	385.41	6283.75	1408.92	461.66	87.48	300.80	3604.90	27919.56
2009	15114.90	355.00	323.37	6057.14	1411.79	460.66	82.52	285.50	3481.10	27584.06
2010	14184.40	391.30	494.93	6591.37	1411.85	473.13	82.39	292.00	3367.90	27311.75
2011	14985.20	336.10	518.64	6766.09	1443.18	508.77	82.31	280.40	3180.20	28123.28
2012	14488.60	303.30	452.44	7143.51	1444.10	505.43	80.94	271.15	3238.30	27944.71
2013	15548.60	255.80	273.66	7529.38	1394.09	490.39	82.16	264.24	3109.40	28959.00
2014	14940.69	249.64	333.46	8188.35	1370.94	491.69	79.62	257.86	2994.40	28912.66
2015	15055.80	272.49	241.07	8356.98	1325.55	483.93	76.17	258.66	2694.25	28785.80
2016	14672.04	348.00	306.36	8780.94	1345.95	483.47	73.55	261.58	2481.60	28776.08
2017	14702.53	534.67	329.32	9186.41	1356.76	475.51	72.42	259.12	2398.52	29323.98
2018	14879.51	589.79	286.82	9276.29	1352.32	467.57	66.90	250.34	2342.90	29517.34
2019	15582.14	376.90	231.72	9171.55	1340.40	479.33	67.78	245.95	2332.99	29832.65

	Grain (wheat, rye, barley etc.)	Pulses (beans, peas)	Industrial crops (sugar beet, flax, hemp etc.)	Oilseeds (sunflower, soybeans, rapeseeds)	Potato	Vegetables	Melons and gourds	Fodder crops	Grasses for hay and green mass	TOTAL
2020	15594.68	340.17	230.12	9250.67	1356.45	490.06	66.08	244.09	2074.64	29651.87
2021	16298.31	343.59	239.82	9287.37	1314.09	485.06	64.65	231.81	2084.99	30356.67

Table A3.3.16. The yields of crop harvest by main crop groups, thousand t

	Grain (wheat, rye, barley etc.)	Pulses (beans, peas)	Industrial crops (sugar beet, flax, hemp etc.)	Oilseeds (sunflower, soybeans, rapeseeds)	Potato	Vegetables	Melons and gourds	Fodder crops	Grasses for hay and green mass	TOTAL
1990	49323	3205	45175	2916	16602	6238	682	25277	187544	336973
1991	38067	2146	36822	2618	14376	5494	650	21045	175830	297054
1992	35551	2986	29208	2388	20147	4907	153	16539	145787	257674
1993	44609	3134	34397	2175	20894	6316	314	19747	161223	292815
1994	34687	2848	28658	1756	16063	5152	181	14226	114901	218475
1995	33770	1701	30211	3129	14689	5879	494	13242	125549	228665
1996	25326	1218	23322	2326	18377	5065	361	10509	90556	177061
1997	36088	1206	17892	2581	16720	5164	312	11416	96750	188130
1998	27017	765	15696	2590	15404	5501	267	9002	71211	147455
1999	25786	697	14208	3231	12719	5331	477	7356	54665	124472
2000	26519	715	13375	3900	19833	5833	373	7264	49520	127334
2001	40514	896	15751	2639	17347	5916	354	8433	44407	136258
2002	38383	809	14593	3480	16624	5830	404	8150	40041	128317
2003	19661	571	13515	4631	18456	6545	382	8665	34729	107160
2004	41029	811	16741	3728	20762	6968	369	9091	32305	131805
2005	37296	757	15565	5694	19464	7300	311	9087	28787	124261
2006	33512	748	22468	6897	19467	8066	688	8567	25578	125990
2007	28967	358	17005	5954	19096	6839	482	8108	21060	107869
2008	52708	550	13458	10728	19542	7966	523	8665	22985	137131
2009	46150	671	10077	9834	19666	8344	635	8133	20723	124241
2010	38698	591	13760	10455	18707	8076	751	7479	19515	118048
2011	56253	492	18750	12466	24245	9833	729	8135	22353	153278
2012	46475	505	18456	12533	23250	10019	799	7693	19283	139023
2013	62686	372	10800	16222	22264	9773	795	8018	19722	150657
2014	64404	503	15751	16591	24135	10114	707	7745	19345	159299
2015	60904	526	10340	17342	21348	9728	602	6992	17552	145354
2016	66596	905	14042	19632	22269	9934	606	7375	18180	160996
2017	62056	1277	14901	18814	22739	9778	457	7259	15683	152969
2018	70287	984	13982	21841	22989	9950	525	7290	15929	163783
2019	75789	739	10219	22748	20748	10204	581	6985	14945	162962
2020	65641	632	9165	18892	21326	10152	518	6646	14147	147124
2021	86663	712	10871	23308	21847	10442	526	6383	14875	175639

The amount of nitrogen appeared as a result of humification of organic fertilizers (N_j) is calculated by multiplying the values for the amount of their application (by type) by the value of nitrogen content in them (excluding direct and indirect emissions of nitrogen), equation A3.3.8:

$$N_j = N'_j \times k_r, \qquad \text{(A3.3.8)}$$

where N_j is the amount of nitrogen introduced into the soil with organic fertilizers (this factor accounts for nitrogen loss through leaching processes - the IPCC default value of 30% was used), t N;
k_r - manure humification factor, %.

Amount of nitrogen introduced into soil with organic fertilizers, calculated under equation A3.3.9:

$$N'_j = (N_{Aj} - V_m) \times d_j, \qquad \text{(A3.3.9)}$$

where N_{Aj} is the amount of nitrogen in manure of animals after its storage (in the j system), just before introduction into the soil, t N;
V_m - direct nitrogen emissions released annually at application of organic fertilizers, t N/ha;
d_j - the conversion rate for organic fertilizer into the equivalent of standard bedding manure, relative units.

Table A3.3.17 provides the amounts of applied to soils for the crop production

Table A3.3.17. Fertilization of Cropland and Grassland

	Organic fertilizers applied, thousand t		Mineral fertilizers applied, thousand t by 100% active matter	
	Cropland	Grassland	Cropland	Grassland
1990	257131	974	1784	57,50
1991	229697	804	1522	45,10
1992	202263	633	1259	32,70
1993	174829	462	996	20,30
1994	143424	413	788	14,30
1995	112019	363	580	8,31
1996	80615	314	372	2,31
1997	64050	384	413	2,71
1998	46659	280	406	3,04
1999	39403	332	327	1,87
2000	28410	303	223	0,90
2001	26535	252	318	0,85
2002	22685	202	313	0,79
2003	17449	151	272	0,74
2004	15083	100	365	0,68
2005	13246	61	377	0,39
2006	13027	49	467	0,43
2007	11911	36	578	0,29
2008	10466	30	736	0,34
2009	10433	11	635	0,22
2010	9874	13	775	0,22
2011	9846	11	899	0,17
2012	9638	11	928	0,25
2013	9602	2	1041	0,20
2014	10183	1	1053	0,29
2015	9989	1	1016	0,11
2016	9466	4	1227	0,29
2017	9614	3	1396	0,20
2018	12109	5	1563	0,20
2019	11924	6	1632	0,23
2020	11898	1	1946	0,40
2021	12361	0	1999	0,30

The direct emissions of nitrogen released annually at application of organic fertilizer is calculated in the Agriculture sector.

Conversion factors for the different types of organic fertilizers to the equivalent amount of standard bedding manure are presented in Table A3.3.18. The humification of bedding manure factor [18] is for Polissia 0.042, Forest Steppe 0.054, Steppe 0.059.

Table A3.3.18. Organic fertilizers to the equivalent bedding manure conversion factors, relative units

Organic fertilizers	Factor
Bedding manure (77% humidity)	1.0
Other manure: - semi-liquid, humidity does not exceed 92%	0.5
- liquid, humidity 93-97%	0.25
Peat manure compost	1.5
Peat litter compost	2.0

Organic fertilizers	Factor
Poultry manure	1.4

Information on the amount of direct nitrous oxide emissions at crop residues (N_{CR}) and organic fertilizers (V_m) introduction into soil is also taken into account during GHG inventory in the Agriculture sector.

The estimations include the factors accounting for gaseous nitrogen losses at application of mineral nitrogen fertilizers to soil on the basis of expert assessments and analysis of domestic studies [31] - 14.5%. The estimations also take into account the amount of nitrogen introduced into soil from the atmosphere - 2-5 kg/ha [28]. The conservative value used for the estimates was 2.5 kg/ha. Another section of nitrogen input into soil is the symbiotic nitrogen fixation with legumes (Table A3.3.19) [17].

Table A3.3.19. Symbiotic nitrogen fixation factors, kg/t

Crop	**Nitrogen fixation**
Peas for hay	10
Peas for green mass	3
Legumes	18
Annual grasses, hay	8
Annual grasses for green mass	2
Vetch	15
Perennial legumes for hay	24
Legume cereals for hay	24
Lucerne for hay	27
Clover for hay	24
Clover for green mass	5
Hayfields and pastures for hay	4

The credit part of equation 3.3.6 is the sum of the amount of mineralized humus in the inventory year in view of the crop and soil type (A3.3.10):

$$N_{M_{is}} = \left[N_i^* - \left(\frac{N_{fi}+N_{ri}}{2} + v_j \times N_j\right)\right] \times k_{mnr}, \quad \text{(A3.3.10)}$$

where $N_{M_{is}}$ is nitrogen emissions from humus mineralization at growing of crop i on soil s, t N/year;
N_i^* - the volume of nitrogen removed by agricultural crops in the inventory year, t N/year;
N_{fi} - the volume of nitrogen from soil fertilizer input into soil, t N/year;
N_{ri} - the volume of nitrogen from organic residues input into soil, t N/year;
½ - the factor for nitrogen removal by plants consumed by roots of agricultural crops;
v_j - the average amount of available nitrogen nutrient in animal manure factor, kg/t (Table A3.4.20);
N_j - the amount of nitrogen introduced into soil with organic fertilizers (equation A3.3.10) t N/year;
k_{mnr} - the factor to consider the links among the processes of nitrogen consumption by crops and humus mineralization, p.p.

Table A3.3.20. The average amount of nitrogen available to plants in animal manure

Animal species	**Nitrogen content**
Spring application (for all soil types)	
Semi-liquid (kg/1,000 l)	
Cows	25
Calves	19
Piglets	41
Pigs	25
Hens	63
Bedding manure (kg/t)	
Cows	16
Piglets	22
Hens (wet)	68
Hens (humid)	129
Broilers	142
Mushroom compost	18

It should be noted that the amount of nitrogen coming into the soil with organic residues of roots of perennial grasses (N_{ri}) should be multiplied by 0.25, because the duration of the plants' life cycle is 4 years.

The value of the nitrogen coming into the soil with fertilizers, which are calculated based on the total amount of mineral fertilizers (in weight units) by multiplying them by the corresponding factors, should include the amount of direct and indirect emissions of nitrogen. As already noted, the volumes of direct and indirect emissions of nitrogen from soil application of nitrogen-containing substances (such as fertilizers or plant residues) are considered in the Agriculture sector.

The amounts of nitrogen removals are determined for the plant species based on standard indicators of nitrogen removal in the main product and by-product harvest of crops, Table A3.3.21 [32].

Table A3.3.21. Standard removal factor of nutrients with the harvest of agricultural crops

Economic regions* and natural zones	**Removal of nitrogen per 1 ton of product, kg**			**Absolute dry matter of the product, %**		**Ratio of by-products vs main products**
	main products	**by-products**	**totally**	**main products**	**by-products**	
						Winter wheat
Ukraine, on average	18.6	4.5	26.7	86	86	1.8
Donetsko-Dniprovsky	17.5	4.1	24.5	86	86	1.7
Forest-Steppe	16.5	4.8	24.5	86	86	1.7
Steppe	18.7	3.6	25.0	86	86	1.7
Southwestern	19.4	4.9	29.1	86	86	2.0
Forrest and Meadow	19.3	4.4	26.7	86	86	1.7
Forest-Steppe	19.7	5.3	31.2	86	86	2.2
Southern	19.6	4.6	27.8	86	86	1.8
Steppe	18.4	5.5	27.2	86	86	1.6
						Winter wheat (under irrigation)
Ukraine, on average	19.6	4.3	27.3	86	86	1.8
						Winter rye
Southwestern	16.5	4.8	26.1	86	86	2.0
						Winter barley
Southern	15.0	5.7	22.4	86	86	1.3
						Spring barley
Ukraine, on average	16.8	5.4	23.8	86	86	1.3
Donetsko-Dniprovsky	16.7	5.6	24.5	86	86	1.4
Forest-Steppe	14.4	4.9	20.3	86	86	1.2
Steppe	19.1	6.5	28.9	86	86	1.5
Southwestern	16.5	5.2	23.3	86	86	1.3
Forrest and Meadow	16.7	5.3	23.1	86	86	1.2
Forest-Steppe	16.3	5.1	23.1	86	86	1.3
Southern	18.5	6.0	25.7	86	86	1.2
						Spring cereals
Ukraine, on average	16.8	5.4	23.8	86	86	1.3
Donetsko-Dniprovsky	16.7	5.6	24.5	86	86	1.4
Southwestern	16.5	5.2	23.3	86	86	1.3
Southern	18.5	6.0	25.7	86	86	1.2
						Oats
Ukraine, on average	17.4	6.6	26.6	86	86	1.4
						Maize for grain
Ukraine, on average	13.7	6.4	22.2	86	86	1.3
Donetsko-Dniprovsky	14.6	6.2	23.1	86	84	1.4
Forest-Steppe	15.7	5.0	24.5	86	72	1.8
Steppe	14.1	6.9	22.1	86	91	1.2
Southern	13.5	6.9	21.9	86	93	1.2
						Maize for grain (under irrigation)
Ukraine, on average	13.7	7.0	22.0	86	92	1.2

Economic regions* and natural zones	Removal of nitrogen per 1 ton of product, kg			Absolute dry matter of the product, %		Ratio of by-products vs main products
	main products	by-products	totally	main products	by-products	
Millet						
Ukraine, on average	16.6	5.2	23.0	86	86	1.2
Buckwheat						
Ukraine, on average	18.1	8.8	37.5	86	83	2.2
Rice						
Ukraine, on average	10.8	5.4	15.8	86	90	0.9
Peas						
Ukraine, on average	31.8	10.1	48.7	86	80	1.7
Long-stalked flax						
Ukraine, on average	5.6	35.4	53.8	81	88	0.6
Hemp						
Ukraine, on average (fiber)	6.3	7.8	60.0	87	81	0.6
Ukraine, on average (seeds)	37.4	-	-	-	-	-
Sugar beet						
Ukraine, on average	2.02	3.62	4.19	22.4	14.2	0.6
Donetsko-Dniprovsky	2.02	4.05	3.96	22.9	15.8	0.5
Forest-Steppe	1.99	3.84	3.72	21.9	14.7	0.4
Steppe	2.19	4.36	4.41	23.8	17.1	0.5
Southwestern	2.03	3.42	4.29	22.1	13.4	0.7
Forest-Steppe	1.99	3.43	4.29	22.3	13.3	0.7
Sugar beet (under irrigation)						
Ukraine, on average	1.91	4.86	4.78	21.1	15.3	0.6
Sunflower						
Ukraine, on average	22.6	7.9	40.7	88	86	2.2
Donetsko-Dniprovsky	21.7	7.9	37.1	88	86	2.2
Forest-Steppe	24.2	7.7	43.5	88	87	2.5
Steppe	21.4	7.9	38.8	88	85	2.2
Southern	24.6	8.1	40.8	88	86	2.0
Soy						
Ukraine, on average	53.7	7.3	61.7	86	88	1.1
Potato						
Ukraine, on average	3.6	3.0	5.0	22.5	19.5	0.5
Donetsko-Dniprovsky	3.8	3.2	5.1	22.5	20.0	0.4
Southwestern	3.5	2.9	5.0	22.5	19.4	0.5
Forrest and Meadow	3.6	3.0	5.1	22.6	19.1	0.5
Forest-Steppe	3.4	2.7	4.7	22.3	20.0	0.5
Fodder beet						
Southwestern	1.9	4.7	3.5	13.2	14.1	0.3
Fodder turnip						
Ukraine, on average	2.1	4.3	3.2	10.8	12.1	0.25
Turnips						
Ukraine, on average	1.6	-	-	9.1	-	-
Cabbage (under irrigation)						
Ukraine, on average	1.9	3.2	3.5	7.7	12.7	0.5
Cucumbers (under irrigation)						
Ukraine, on average	1.6	3.6	3.5	4.8	15.3	0.5
Tomatoes (under irrigation)						
Ukraine, on average	1.5	3.9	2.4	5.6	18.8	0.2
Red beet						
Ukraine, on average	3.6	-	-	14.0	-	-
Eggplant (under irrigation)						
Ukraine, on average	1.4	4.4	2.2	7.7	18.1	0.2
Onion						
Ukraine, on average	1.7	4.9	2.9	13.2	22.2	0.2
Carrots						
Ukraine, on average	1.5	3.4	2.9	10.9	15.8	0.4
Pepper						

Economic regions* and natural zones	Removal of nitrogen per 1 ton of product, kg			Absolute dry matter of the product, %		Ratio of by-products vs main products
	main products	by-prod-ucts	totally	main products	by-prod-ucts	
Ukraine, on average	2.0	3.7	5.0	9.5	15.4	0.8
Tobacco						
Ukraine, on average	35.3	15.3	47.5	81	82	0.8
Lavender						
Southern	7.6	7.6	19.8	35.6	40.4	1.6
Clary sage						
Ukraine, on average	8.4	4.8	14.6	30	30	1.3
Mint						
Ukraine, on average	24.1	15.3	37.9	86	85	0.9
Maize for silage						
Ukraine, on average	-	-	3.2	21.8	-	-
Donetsko-Dniprovsky	-	-	3.5	25.1	-	-
Southwestern	-	-	3.0	19.5	-	-
Southern	-	-	3.8	25.5	-	-
Maize for silage (under irrigation)						
Ukraine, on average	-	-	3.3	22.1	-	-
Annual grasses (hay, legume-cereals)						
Ukraine, on average	-	-	18.8	84	-	-
Donetsko-Dniprovsky	-	-	14.8	84	-	-
Southwestern	-	-	19.0	84	-	-
Southern	-	-	19.8	84	-	-
Annual grasses (hay, cereals)						
Ukraine, on average	-	-	13.2	84	-	-
Donetsko-Dniprovsky	-	-	12.5	84	-	-
Southwestern	-	-	15.4	84	-	-
Annual grasses, total (hay)						
Ukraine, on average	-	-	15.9	84	-	-
Donetsko-Dniprovsky	-	-	13.5	84	-	-
Southwestern	-	-	17.9	84	-	-
Southern	-	-	19.8	84	-	-
Perennial grasses (hay, alfalfa)						
Ukraine on average (during irrigation)	-	-	29.8	84	-	-
Perennial grasses (hay, legume-cereals)						
Ukraine, on average	-	-	20.9		-	-
Perennial grasses (hay, clover)						
Ukraine, on average	-	-	24.3	84	-	-
Donetsko-Dniprovsky	-	-	19.3	84	-	-
Southwestern	-	-	24.8	84	-	-

* The economic regions of Ukraine during the times of the USSR included the following oblasts: Donetsko-Dnieprovsky economic region - Dnipropetrovsk, Donetsk, Zaporizhya, Kirovograd, Luhansk, Poltava, Sumy, and Kharkiv Oblasts; Southwest - Vinnytsia, Volyn, Zhytomyr, Ivano-Frankivsk, Kyiv, Rivne, Ternopil, Khmelnytsky, Cherkasy, Chernivtsi, and Chernihiv Oblasts; Southern - Odessa, Mykolaiv, Kherson Oblasts, and the AR Crimea

The factor to consider the links between the processes of plant consumption of nitrogen and the processes of humus mineralization of *(k_{mnr})* in equation 3.3.11 is calculated by taking into account the correction factors for the soil particle size distribution and the type of agricultural plants based on the equation:

$$k_{mnr} = k_i \times k_s, \qquad \text{(A3.3.11)}$$

where k_i is mineralization factors to account for the effect of the type of crop cultivated;
k_s - factors to account the soil particle size distribution.

The above factors are shown in Tables A3.3.22 and 3.3.23, respectively [18].

Table A3.3.22. The factors to account the type of agricultural crops at soil humus mineralization, relative units

Crop	Soil and climatic zone		
	Polissia	Forest Steppe	Steppe
Winter grains	0.9	0.7	1.35
Sugar beet	1.7	1.5	1.59
Maize for grain	1.4	1.1	1.56
Maize for silage	0.3	0.25	1.47
Barley	0.05	0.7	1.23
Oats	0.27	0.82	1.20
Millet	0.00	0.72	1.10
Buckwheat	0.12	1.06	1.10
Spring wheat	-	-	1.10
Vegetables	1.34	1.20	1.60
Flax	0.90	-	-
Potato	1.50	1.20	1.61
Sunflower	-	1.00	1.39
Annual grasses	0.80	0.80	1.10
Perennial grasses	0.55	0.30	0.60

Table A3.3.23. The factors to account for the soil particle size distribution at soil humus mineralization, p.p.

The soil group based on particle size distribution	Mineralization factor
Sandy	1.8
Sandy loam	1.4
Light loamy	1.2
Medium loamy	1.0
Heavy loamy and clay	0.8

Equation A3.3.8 includes the factor, which allow to consider the ratio of carbon and nitrogen (C:N) content in ploughed layer humic substances. Values of the parameters are shown in Table A3.3.24 [32].

Table A3.3.24. The ratio of carbon and nitrogen (C:N) content in ploughed level humic substances for various types of soils

Types of soil	Humus content, %	Organic C in the general initial soil, %	Gross nitrogen, %	C:N
Polissia soils				
Sod-podzolic clay and sandy soils on water-glacial sands	0.57	0.33*	0.03	11.02
Sod-mesopodzolic sabulous soils on layered water-glacial sands	0.87	0.5*	0.05	10.09
Sod-mesopodzolic light loamy soils on water-glacial loam underlaid by layered sands	1.17	0.67	0.07	9.57
Soils of the Forest Steppe				
Light gray podzolized soils on loess	4.19	2.43	0.23	10.57
Gray podzolized soils on loess	2.03	1.18	0.13	9.08
Dark gray podzolized soils on loess	7.29	4.23	0.14	10.58
Dark gray degraded soils on loess	3.48	2.02	0.21	9.62
Degraded black soil on loess	3.53	2.05	0.21	9.76
Typical thick low-humic black soil on loess	4.58	2.66	0.30	8.87
Typical thick medium-humic black soil on loess	5.61	3.25	0.29	11.21
Meadow black soil on loess loam	4.90	2.84	0.28	10.15
Alkali meadow deep black soil on loess loam	2.40	1.39	0.14	9.94
Meadow surface alkaline loamy soil on alluvial sediments	6.90	4.00	0.43	9.30
Steppe soils				
Ordinary thick medium-humic black soil on loess	6.10	3.54*	0.30	11.79
Ordinary thick low-humic black soil on loess	4.70	2.73*	0.27	10.10
Ordinary medium-thick low-humic black soil on loess	4.60	2.90	0.25	11.60
Black soils on clay shale eluvium	4.59	2.66*	0.23	11.58
Black soils on sandy shale eluvium	3.30	1.91*	0.16	11.96
Highly alkalinized saline balck soils on saline Paleogene clays	3.00	1.74*	0.15	11.60

Types of soil	Humus content, %	Organic C in the general initial soil, %	Gross nitrogen, %	C:N
Southern micellar-carbonate black soils on loess	3.40	1.97*	0.22	8.96
Dark brown alkaline (arable) on loess	3.40	1.97*	0.16	12.33
Brown alkaline soils on loess	3.60	2.09*	0.21	9.94
Brown medium alkali on loess	4.10	1.97	0.20	9.85
Meadow black soil surface gley low-solodized soils on gleying loess	5.20	2.33	0.27	8.63
Solodized gley soils (gley-malt) on gleyed loess	4.40	2.47	0.26	9.50
Soils of the Carpathian brownsoil-forest region				
Acid moderate-humic brownsoil on eluvium shale	21.04	12.20*	1.06	11.51
Meadowlike brownsoil acid on ancient lake alluvial sediments	5.91	3.43	0.29	11.83
Soils of the mountain Crimea				
Ordinary micellar-carbonate foothills black soil on ancient clay talus	3.60	2.66	0.25	10.64

Calculated by multiplying the value of the humus content in soil by the factor of 1/1.724.

To perform estimations using the described method, it is necessary to know the areas by soil types in Ukraine (Table A3.3.25), as well as take into account the distribution of soil types by natural zones (Table A3.3.26) [32].

Table A3.3.25. The area of soil types in Ukraine, ha

Soil	Area of the soils		Area of arable land		
	kha	%	kha	% of the total	% of arable land
Sod-podzolic sabulous and clay sabulous	1573.0	3.5	1015.0	64.5	3.5
Sod-podzolic gley	1916.3	4.3	1140.7	59.5	3.6
Gray forest	7924.0	17.8	6719.1	84.8	21.3
Typical black soils (on-eroded and eroded) on loess rocks	6272.2	14.1	5731.4	91.4	18.1
Ordinary black soils (on-eroded and eroded) on loess rocks	10395.0	23.4	8760.0	84.3	27.7
Southern black soils (on-eroded and eroded) on loess rocks	6237.9	14.1	4662.4	74.7	14.8
Meadow black soil, mainly on loess rocks	1124.9	2.5	700.7	62.3	2.2
Dark brown and chestnut in loess rocks	1489.9	3.4	1241.0	83.3	3.9
Meadow, mainly on alluvial rocks	1939.1	4.4	663.0	34.2	2.1
Swampy, peat swampy, and peatlands	2061.8	4.6	83.5	3.8	0.26
Alkali and solodized	537.8	1.2	256.1	47.6	0.8
Sod	1627.1	3.7	396.3	24.4	1.3
Brownsoil, sod-brownsoil	956.4	2.2	192.7	20.1	0.6
Brown mountain, mountain meadow	41.8	0.1	7.2	17.2	0.02
Rock exposures	311.0	0.7	21.6	6.9	0.1
TOTAL	44406	100	31586.3	71.7	100

Table A3.3.26. Characteristics of agricultural land by the mechanical composition (without homestead land for personal use), kha

Region	Total area as on November 1, 1990	Of them explored	Mechanical composition of soils						
			Hard and medium-clay	Light clay	Hard loamy	Average loamy	Light loamy	Sandy loam	Arenaceous
1	2	3	4	5	6	7	8	9	10
AR Crimea	1729.2	1668.4	378.10	861.20	340.50	70.80	15.00	2.30	0.50
Vinnytska	1850.2	1824.9	8.00	30.50	579.20	1042.40	135.10	17.50	5.90
Volynska	967.5	960.2	0.00	0.00	1.10	9.60	269.10	216.60	289.50
Dnipropetrovska	2373.1	2351.4	14.90	672.40	1251.8	334.20	39.90	27.30	10.20
Donetska	1917.3	1896.1	161.70	1265.3	338.70	94.20	14.90	19.90	1.40
Zhytomyrska	1475.0	1455.2	0.00	0.00	1.20	203.20	441.10	591.30	195.90
Transcarpathian	357.2	343.2	7.30	34.60	91.70	155.50	43.90	9.70	0.50
Zaporizhska	2160.5	2117.7	235.20	1241.2	417.50	154.00	51.50	16.00	2.30
Ivano-Frankivska	340.1	333.4	6.40	47.40	88.40	100.70	82.90	6.10	0.00
Kyivska	1539.3	1522.1	0.00	0.00	5.80	275.40	778.90	241.30	119.50
Kirovohradska	1938.3	1892.6	0.80	1041.8	626.60	182.20	21.90	8.30	1.10
Luganska	1816.3	1807.3	24.10	735.40	789.60	179.10	44.20	29.30	5.60
Lvivska	1118.3	1113.8	2.30	4.80	32.60	210.50	555.80	149.60	77.00
Mykolaivska	1934.8	1902.7	18.60	980.60	750.10	126.40	16.50	6.60	3.60
Odesska	2445.9	2427.9	54.20	400.40	1649.2	245.90	36.50	35.40	6.30
Poltavska	2054.3	2027.2	0.00	0.90	416.70	1129.50	362.30	57.10	24.00
Rivnenska	815.6	798.9	0.00	0.00	0.50	37.20	350.70	123.70	188.10
Sumska	1618.0	1610.9	0.20	6.70	101.50	719.00	474.30	189.40	46.80
Ternopilska	962.2	947.2	0.00	0.00	137.60	671.10	92.30	12.90	2.10
Kharkivska	2287.6	2244.7	16.10	1284.7	768.80	117.50	28.70	22.60	5.90
Khersonska	1908.6	1886.5	16.30	436.90	806.20	363.50	159.30	76.00	27.80
Khmelnytska	1437.8	1418.6	0.00	2.20	110.50	656.70	500.30	56.90	12.00
Cherkaska	1293.7	1285.2	0.60	55.10	422.80	458.40	285.60	37.20	8.30
Chernivetska	410.3	408.8	3.80	46.50	179.00	114.20	55.60	8.70	1.00
Chernihivska	1954.3	1943.4	0.00	0.00	0.00	54.10	981.60	579.00	184.10
Total	38705.4	38188.3	948.6	9148.6	9907.7	7705.3	5837.9	2540.7	1219.3

Data on fires on agricultural land is shown in Table A3.3.27.

Table A3.3.27. Distribution of areas damaged by fires by agricultural crops, ha

Crop	2005	2010	2015	2016	2017	2018	2019	2020	2021
Wheat	45.5	143.01	2202.5	1352.8	1526.6	1177.2	1837.0	4502.2	1 987.3
Barley	18.6	76.3	118.1	336.6	285.7	29.6	591.5	95.0	427.3
Maize	28.048	98.87	1718.2	67.2	476.3	103.4	786.0	262.0	73.4
Oats	0.4	0	30.9	0.6	0	0.1	0.7	1.2	0.3
Rye	0	0	10.0	2.5	3.0	0	28.0	23.8	0.0
Millet	0	0	0	3.10	3.5	1.2	0	1.0	0.2
Rice	0	0	0	0	0	0	0	0	8.5
Buckwheat	0	3.5	0	0	0	0	0	0	0
Peas	0	0	0	0.5	6.0	0	0	0	4.5
Sunflower	0	0	0	0.2	41.0	20.5	0	0.8	0.1
Soybeans	0	10.0	8.7	22.61	0	53.2	48.2	0.3	0
Rapeseed	0	0	0	0	0	0	0	0	20.7
Spring vetch	0	6.0	0	0	0	0	0	0	0
Medicago	0	0	2.3	2.0	0	0	0	0.9	15.0
Sorghum	0	0	0	0.5	6.9	2.0	0	0	0

Crop	2005	2010	2015	2016	2017	2018	2019	2020	2021
Phalaris	0	0	0	169.75	0	23.6	0	0.3	0

Estimation of CH_4, N_2O, CO, and NO_x emissions was conducted under Tier 1 of 2006 IPCC (2006 IPCC equation 2.27) using default EFs.

To estimate emissions of non-methane volatile organic compounds, 2013 EMEP/EEA Emission Inventory Guidebook [8] was used. In accordance with the methodological guidelines, estimation of NMVOC emissions was carried out according to equation A3.3.12:

$$E_{pollutant} = AR_{residues\_burnt} \times EF_{pollutant} \quad (A3.3.12)$$

where:

$E_{pollutant}$ - emissions of pollutant (kg);

$AR_{residues\_burnt}$ - the indicator of activity data, the burnt residue mass (kg of dry matter);

$EF_{pollutant}$ - the emission factor for pollutant (kg/kg of dry matter).

To determine the mass of burnt residues, equation A3.3.13 was used:

$$AR_{reidues\_burnt} = A \times M_B \times C_f \quad (A3.3.13)$$

where:

A - burned area, ha;

M_B - mass of fuel available for combustion, t/ha;

C_f - combustion factor (dimensionless).

To estimate emissions of non-methane volatile organic compounds, the default emission factor was used from Table 3-1 of 2013 EMEP/EEA Emission Inventory Guidebook [8].

The same M_B and C_f values were used as for estimation of CH_4, CO, N_2O, and NO_x. Their source was Table 2.4. of the 2006 IPCC Guidelines [1].

Also, information was obtained on the number of fires and the areas affected by fires on pastures and wetlands (Table A3.3.28) from the Ukrainian Scientific Research Institute of Civil Protection.

Table A3.3.28. The number of fires and the area of burnt pastures and non-forest peatlands in Ukraine

	Destroyed and damaged pastures, ha	Destroyed and damaged non-forest peatlands, ha
2000	-	-
2001	-	-
2002	-	-
2003	-	-
2004	-	-
2005	752	156
2006	193	259
2007	338	90
2008	157	125
2009	230	310
2010	1049	242
2011	839	123
2012	733	89
2013	739	51
2014*	876	420
2015*	2533	1167
2016*	299	33
2017*	861	221
2018*	860	271
2019*	929	515

	Destroyed and damaged pastures, ha	Destroyed and damaged non-forest peatlands, ha
2020*	5589	311
2021*	685	55
*Data of the Ukrainian Scientific Research Institute of Civil Protection corrected with analytical study [6]		

Statistics on the number of fires has been conducted since 2000, and that on the areas - only since 2005.

The estimation of GHG emissions from burning of pastures was produced using Equation 2.27 of the 2006 IPCC Guidelines [1]. The default EFs were also used.

Nitrogen emissions from mineralization of soil Carbon during land-use conversions were estimated using the Tier 1 method (Equations 11.1 and 11.8 of the 2006 IPCC Guidelines). For lands converted to cropland, nationally determined C:N ratio was used (table A3.3.22), for grassland the default ratio was used - 15.

A3.3.3 Methodological aspects of the HWP category

Calculations in HWP category was performed with Tier 1 method by production approach. With necessity to comply requirements of KP-Supplement it was decided to apply KP reporting approach to reporting under the Convention also.

The main data sources for the calculations are the State Statistic Service of Ukraine (production of sawnwood, industrial roundwood production, import and export, production for particular years, import and export of pulp) and FAO. For recent years due to necessity to comply with legislation the State Statistic Service of Ukraine do not provide data of pulp production, this data was derived from the Ukrainian Association of Pulp and Paper industry «UkrPapir».

Activity data for the calculations is provided in table A3.3.29. For the years 1990-1991 FAO data for production of wood panels, paper and paperboard is absent. Thus, GDP data was used to derive data for these years using splicing techniques.

Table A3.3.29. Activity data for HWP category calculations

	Sawnwood production, m^3	Industrial roundwood production, m^3	Industrial roundwood export, m^3	Industrial roundwood import, m^3	Wood panels production, m^3	Paper and paperboard production, m^3	Pulp production, t	Pulp export, t	Pulp import, t
1990	7 441 000	8 900 000	No data	No data	1 564 365	312 325	104 049	No data	No data
1991	6 106 000	7 600 000	No data	No data	1 395 154	267 888	89 685	No data	No data
1992	4 700 000	7 000 000	693	No data	1 215 000	228 790	75 810	0	2 112
1993	3 882 000	6 600 000	1 100	200	988 000	145 290	47 699	0	2 100
1994	3 124 000	6 200 000	1 100	200	614 000	78 500	51 167	0	2 100
1995	2 917 000	5 900 000	20 100	470 300	560 000	85 200	60 751	0	2 100
1996	2 296 000	5 200 000	303 692	391 662	382 000	292 890	33 988	600	63 200
1997	2 306 000	4 741 900	452 013	167 079	372 000	264 000	26 334	500	48 100
1998	2 258 000	4 659 000	825 459	90 658	355 000	292 900	29 537	300	53 445
1999	2 141 000	4 700 500	2 305 667	83 828	392 000	310 900	37 302	301	54 827
2000	2 127 000	5 239 200	1 259 205	94 890	490 000	411 000	38 639	301	54 827
2001	1 995 000	5 350 100	1 086 604	112 020	659 000	479 900	40 777	50	64 600
2002	1 950 000	5 584 400	1 757 505	89 177	868 300	531 600	41 243	0	73 030
2003	2 197 000	5 788 900	1 845 406	116 784	970 000	618 037	39 633	0	87 090
2004	2 414 000	6 536 500	2 607 308	135 505	1 239 000	722 999	34 400	310	95 050
2005	2 409 000	6 617 000	2 394 944	170 124	1 443 000	768 010	38 600	0	91 440
2006	2 385 000	6 906 700	2 205 802	172 537	1 604 000	804 000	31 400	949	88 049
2007	2 525 000	7 364 400	2 586 028	133 351	1 944 000	937 001	32 300	344	107 841

	Sawnwood production, m^3	Industrial roundwood production, m^3	Industrial roundwood export, m^3	Industrial roundwood import, m^3	Wood panels production, m^3	Paper and paperboard production, m^3	Pulp production, t	Pulp export, t	Pulp import, t
2008	2 266 000	7 062 600	2 066 372	125 803	1 944 000	937 001	29 800	99	95 636
2009	1 753 000	6 181 600	1 883 311	11 955	1 522 000	813 999	4 100	12	82 726
2010	1 736 000	7 536 000	2 933 874	18 519	1 751 000	857 001	5 800	66	84 131
2011	1 888 000	7 989 400	3 008 873	22 268	1 989 000	986 998	4 100	53	77 385
2012	1 823 000	7 850 800	3 018 713	19 808	2 097 300	1 123 060	0	0	73 421
2013	1 804 000	8 102 100	3 453 913	14 009	2 167 700	1 079 350	0	0	68 819
2014	1 780 900	8 158 792	3 518 169	7 699	1 886 000	1 079 350	0	0	61 454
2015	1 928 954	8 302 600	2 976 300	14 000	1 936 000	1 079 350	0	0	49 924
2016	2 150 842	8 311 300	2 074 100	14 000	2 267 700	1 079 350	0	0	57 368
2017	2 498 003	7 296 600	12 100	9 290	3 736 700	983 000	0	0	58 928
2018	3 270 975	8 976 000	3 300	23 117	5 780 700	1 155 000	0	0	66 295
2019	3 095 911	9 303 400	3 374	4 667	5 163 700	1 033 000	0	0	72 059
2020	3 018 601	8 996 300	142	7 425	5 050 700	1 039 000	0	0	76 052
2021	2 212 248	8 215 000	400	52 091	6 183 700	982 429	0	0	79 600

A3.4 Waste (CRF Sector 5)

This annex presents additional information regarding activity data, emission factors, and estimations of GHG emissions along the time series for the period of 1990-2021. All the data relate to category 5.A "Solid Waste Management" of the "Waste" Sector.

A3.4.1 Information on the amount of solid waste dumped in landfills and methane emissions adopted for estimations in general and by landfill categories for the period of 1900-2021

Year	Specific MSW generation	The share of MSW dumped on landfills	Specific dumping MSW	Urban population	Weight of dumped solid waste, total	of them:				Unmanaged shallow landfills	Unmanaged deep landfills	Managed landfills
						MSW			industrial organic			
						Total	of it: official*	unofficial**				
	kg/person/year		kg/person/year	thous. people	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons
1900	173.1	0.85	147.2	3590.31	607.64	607.64	528.38	79.26	0.00	251.51	356.13	0.00
1901	173.5	0.85	147.5	3772.55	639.98	639.98	556.51	83.48	0.00	264.90	375.08	0.00
1902	174.0	0.85	147.9	3954.79	672.47	672.47	584.76	87.71	0.00	278.34	394.13	0.00
1903	174.4	0.85	148.2	4137.02	705.10	705.10	613.13	91.97	0.00	291.85	413.25	0.00
1904	174.8	0.85	148.6	4319.26	737.88	737.88	641.64	96.25	0.00	305.42	432.46	0.00
1905	175.2	0.85	148.9	4501.50	770.81	770.81	670.27	100.54	0.00	319.05	451.76	0.00
1906	175.6	0.85	149.2	4683.74	803.87	803.87	699.02	104.85	0.00	332.73	471.14	0.00
1907	176.0	0.85	149.6	4865.98	837.09	837.09	727.90	109.19	0.00	346.48	490.61	0.00
1908	176.4	0.85	149.9	5048.22	870.45	870.45	756.91	113.54	0.00	360.29	510.16	0.00
1909	176.8	0.85	150.3	5230.46	903.95	903.95	786.04	117.91	0.00	374.16	529.79	0.00
1910	177.2	0.85	150.6	5412.70	937.60	937.60	815.30	122.30	0.00	388.08	549.51	0.00
1911	177.6	0.85	151.0	5544.57	962.65	962.65	837.09	125.56	0.00	398.45	564.20	0.00
1912	178.0	0.85	151.3	5676.45	987.80	987.80	858.96	128.84	0.00	408.86	578.94	0.00
1913	178.4	0.85	151.7	5808.32	1013.06	1013.06	880.92	132.14	0.00	419.32	593.74	0.00
1914	178.8	0.85	152.0	5940.19	1038.42	1038.42	902.98	135.45	0.00	429.82	608.61	0.00
1915	179.2	0.85	152.4	6072.07	1063.89	1063.89	925.12	138.77	0.00	440.36	623.53	0.00
1916	179.7	0.85	152.7	6203.94	1089.47	1089.47	947.36	142.10	0.00	450.94	638.52	0.00
1917	180.1	0.85	153.0	6335.81	1115.15	1115.15	969.69	145.45	0.00	461.57	653.57	0.00
1918	180.5	0.85	153.4	6467.68	1140.93	1140.93	992.11	148.82	0.00	472.25	668.68	0.00
1919	180.9	0.85	153.7	6599.56	1166.82	1166.82	1014.62	152.19	0.00	482.96	683.86	0.00
1920	181.3	0.85	154.1	6731.43	1192.81	1192.81	1037.23	155.58	0.00	493.72	699.09	0.00
1921	181.7	0.85	154.4	6834.86	1213.86	1213.86	1055.53	158.33	0.00	502.43	711.43	0.00
1922	182.1	0.85	154.8	6938.28	1234.99	1234.99	1073.90	161.09	0.00	511.18	723.81	0.00
1923	182.5[5]	0.85	155.1	7041.71	1256.20	1256.20	1092.35	163.85	0.00	519.96	736.24	0.00
1924	182.9	0.85	155.5	7145.14	1277.49	1277.49	1110.86	166.63	0.00	528.77	748.72	0.00
1925	183.3	0.85	155.8	7248.56	1298.87	1298.87	1129.45	169.42	0.00	537.62	761.25	0.00

Year	Specific MSW generation	The share of MSW dumped on landfills	Specific dumping MSW	Urban population	Weight of dumped solid waste, total	of them: MSW Total	of them: MSW of it: official*	of them: MSW of it: unofficial**	of them: industrial organic	Unmanaged shallow landfills	Unmanaged deep landfills	Managed landfills
	kg/person/year		kg/person/year	thous. people	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons
1926	183.7	0.85	156.2	7351.99	1320.32	1320.32	1148.11	172.22	0.00	546.50	773.82	0.00
1927	184.1	0.85	156.5	7455.42	1341.86	1341.86	1166.84	175.03	0.00	555.41	786.45	0.00
1928	184.5	0.85	156.9	7558.84	1363.49	1363.49	1185.64	177.85	0.00	564.36	799.12	0.00
1929	184.9	0.85	157.2	7662.27	1385.19	1385.19	1204.51	180.68	0.00	573.35	811.84	0.00
1930	185.3	0.85	157.5	7765.70	1406.98	1406.98	1223.46	183.52	0.00	582.37	824.61	0.00
1931	185.8	0.85	157.9	7998.80	1452.39	1452.39	1262.95	189.44	0.00	601.16	851.23	0.00
1932	186.2	0.85	158.2	8231.91	1497.99	1497.99	1302.60	195.39	0.00	620.04	877.95	0.00
1933	186.6	0.85	158.6	8465.01	1543.78	1543.78	1342.42	201.36	0.00	638.99	904.79	0.00
1934	187.0	0.85	158.9	8698.11	1589.75	1589.75	1382.39	207.36	0.00	658.02	931.73	0.00
1935	187.4	0.85	159.3	8931.22	1635.91	1635.91	1422.53	213.38	0.00	677.12	958.79	0.00
1936	187.8	0.85	159.6	9164.32	1682.25	1682.25	1462.83	219.42	0.00	696.31	985.95	0.00
1937	188.2	0.85	160.0	9397.42	1728.78	1728.78	1503.29	225.49	0.00	715.56	1013.22	0.00
1938	188.6	0.85	160.3	9630.53	1775.49	1775.49	1543.91	231.59	0.00	734.90	1040.59	0.00
1939	189.0	0.85	160.7	9863.63	1822.39	1822.39	1584.69	237.70	0.00	754.31	1068.08	0.00
1940	189.4	0.85	161.0	10096.73	1869.48	1869.48	1625.63	243.84	0.00	773.80	1095.68	0.00
1941	189.8	0.85	161.4	10367.06	1923.65	1923.65	1672.74	250.91	0.00	796.23	1127.43	0.00
1942	190.2	0.85	161.7	10637.39	1978.05	1978.05	1720.04	258.01	0.00	818.74	1159.31	0.00
1943	190.6	0.85	162.0	10907.71	2032.65	2032.65	1767.53	265.13	0.00	841.34	1191.31	0.00
1944	191.0	0.85	162.4	11178.04	2087.48	2087.48	1815.20	272.28	0.00	864.03	1223.44	0.00
1945	191.5	0.85	162.7	11448.37	2142.51	2142.51	1863.06	279.46	0.00	886.81	1255.70	0.00
1946	191.9	0.85	163.1	11718.69	2197.77	2197.77	1911.10	286.67	0.00	909.68	1288.08	0.00
1947	192.3	0.85	163.4	11989.02	2253.23	2253.23	1959.33	293.90	0.00	932.64	1320.59	0.00
1948	192.7	0.85	163.8	12259.35	2308.92	2308.92	2007.75	301.16	0.00	955.69	1353.23	0.00
1949	193.1	0.85	164.1	12529.67	2375.54	2364.81	2056.36	308.45	10.73	978.83	1396.71	0.00
1950	193.5	0.85	164.5	12800.00	2442.38	2420.93	2105.15	315.77	21.45	1002.05	1440.33	0.00
1951	193.9	0.85	164.8	13400.00	2571.92	2539.74	2208.47	331.27	32.18	1051.23	1520.69	0.00
1952	194.3	0.85	165.2	14200.00	2739.92	2697.01	2345.23	351.78	42.90	1116.33	1623.59	0.00
1953	194.7	0.85	165.5	14800.00	2870.49	2816.86	2449.44	367.42	53.63	1165.93	1704.56	0.00
1954	195.1	0.85	165.8	15400.00	3001.54	2937.18	2554.07	383.11	64.36	1215.74	1785.80	0.00
1955	195.5	0.85	166.2	15700.00	3075.73	3000.65	2609.26	391.39	75.08	1242.01	1833.72	0.00
1956	195.9	0.85	166.5	16000.00	3150.16	3064.35	2664.65	399.70	85.81	1268.37	1881.78	0.00
1957	196.3	0.85	166.9	17000.00	3359.17	3262.63	2837.07	425.56	96.54	1350.45	2008.72	0.00
1958	196.7	0.85	167.2	18300.00	3626.67	3519.41	3060.36	459.05	107.26	1456.73	2169.94	0.00
1959	197.2	0.85	167.6	19147.40	3807.98	3690.00	3208.69	481.30	117.99	1527.34	2280.65	0.00

Year	Specific MSW generation	The share of MSW dumped on landfills	Specific dumping MSW	Urban population	Weight of dumped solid waste, total	of them:				Unmanaged shallow landfills	Unmanaged deep landfills	Managed landfills
						MSW			industrial organic			
						Total	of it:					
							official*	unofficial**				
	kg/person/year		kg/person/year	thous. people	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons
1960	197.6	0.85	167.9	19850.60	3962.12	3833.41	3333.40	500.01	128.71	1586.70	2375.43	0.00
1961	198.0	0.85	168.3	20646.80	4134.82	3995.38	3474.24	521.14	139.44	1653.74	2481.08	0.00
1962	198.4	0.85	168.6	21130.20	4247.50	4097.33	3562.90	534.43	150.17	1695.94	2551.56	0.00
1963	198.8	0.85	169.0	21628.00	4363.35	4202.46	3654.31	548.15	160.89	1739.45	2623.90	0.00
1964	199.2	0.85	169.3	22228.80	4499.66	4328.04	3763.52	564.53	171.62	1791.43	2708.23	0.00
1965	199.6	0.85	169.7	22786.00	4627.94	4445.60	3865.74	579.86	182.35	1840.09	2787.85	0.00
1966	200.0[6]	0.85	170.0	23357.90	4759.54	4566.47	3970.84	595.63	193.07	1890.12	2869.42	0.00
1967	202.2	0.85	171.9	23939.30	4936.26	4732.47	4115.19	617.28	203.80	1958.83	2977.43	0.00
1968	204.5	0.85	173.8	24519.00	5115.19	4900.66	4261.45	639.22	214.52	2028.45	3086.74	0.00
1969	206.7	0.85	175.7	25126.10	5302.18	5076.93	4414.72	662.21	225.25	2101.41	3200.77	0.00
1970	208.9	0.85	177.6	25688.60	5482.72	5246.75	4562.39	684.36	235.98	2171.70	3311.03	0.00
1971	211.2	0.85	179.5	26244.00	5664.26	5417.55	4710.92	706.64	246.70	2242.40	3421.86	0.00
1972	213.4	0.85	181.4	26918.20	5873.00	5615.57	4883.11	732.47	257.43	2324.36	3548.64	0.00
1973	215.7	0.85	183.3	27519.20	6069.27	5801.11	5044.44	756.67	268.15	2401.16	3668.11	0.00
1974	217.9	0.85	185.2	28042.60	6251.63	5972.75	5193.69	779.05	278.88	2472.20	3779.43	0.00
1975	220.1	0.85	187.1	28561.00	6435.20	6145.60	5344.00	801.60	289.61	2543.74	3891.46	0.00
1976	222.4	0.85	189.0	29112.50	6628.24	6327.91	5502.53	825.38	300.33	2619.20	4009.04	0.00
1977	224.6[7]	0.85	190.9	29579.60	6805.16	6494.10	5647.04	847.06	311.06	2687.99	4117.17	0.00
1978	229.3	0.85	194.9	30049.20	7057.77	6735.98	5857.38	878.61	321.79	2788.11	4269.66	0.00
1979	234.0	0.85	198.9	30511.50	7312.99	6980.48	6069.98	910.50	332.51	2889.31	4423.68	0.00
1980	238.8	0.85	203.0	30917.90	7559.44	7216.20	6274.96	941.24	343.24	2986.88	4572.56	0.00
1981	243.5	0.85	207.0	31315.80	7807.61	7453.65	6481.43	972.22	353.96	3085.16	4722.45	0.00
1982	248.2	0.85	211.0	31688.90	8053.44	7688.75	6685.87	1002.88	364.69	3182.48	4870.97	0.00
1983	252.9	0.85	215.0	32053.50	8300.62	7925.20	6891.48	1033.72	375.42	3280.34	5020.27	0.00
1984	257.7	0.85	219.0	32492.70	8569.95	8183.81	7116.35	1067.45	386.14	3387.38	5182.57	0.00
1985	262.4[8]	0.85	223.0	32921.30	8841.05	8444.18	7342.77	1101.42	396.87	3495.16	5345.89	0.00
1986	267.1	0.86	229.7	33311.90	9131.46	8723.87	7652.52	1071.35	407.60	3566.07	5565.39	0.00
1987	271.8	0.87	236.5	33731.30	9432.87	9014.55	7977.48	1037.07	418.32	3637.73	5795.14	0.00
1988	276.6	0.88	243.4	34163.70	9741.30	9312.26	8314.52	997.74	429.05	3708.27	6033.03	0.00
1989	281.3	0.89	250.3	34587.60	10050.86	9611.08	8658.63	952.45	439.77	3775.16	6275.69	0.00
1990	286.0[9]	0.90	257.4	34869.20	10323.37	9872.87	8975.33	897.53	450.50	3819.00	6360.20	144.17
1991	277.4	0.90	249.6	35085.20	10046.04	9634.73	8758.84	875.88	411.31	3722.51	6042.15	281.38
1992	268.8	0.90	241.9	35296.90	9762.53	9391.76	8537.97	853.80	370.76	3624.37	5726.74	411.42
1993	260.2	0.90	234.1	35471.00	9453.56	9135.50	8305.00	830.50	318.05	3521.32	5398.64	533.60

Year	Specific MSW generation	The share of MSW dumped on landfills	Specific dumping MSW	Urban population	Weight of dumped solid waste, total	of them:				Unmanaged shallow landfills	Unmanaged deep landfills	Managed landfills
						MSW			industrial organic			
						Total	of it: official*	of it: unofficial**				
	kg/person/year		kg/person/year	thous. people	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons	thousand tons
1994	251.5	0.90	226.4	35400.70	9060.48	8815.41	8014.01	801.40	245.07	3393.93	5022.92	643.63
1995	242.9	0.90	218.6	35118.80	8660.97	8445.63	7677.85	767.78	215.34	3247.73	4673.29	739.95
1996	234.3[10]	0.90	210.9	34767.90	8258.37	8064.66	7331.51	733.15	193.72	3097.56	4336.47	824.34
1997	248.9	0.90	224.0	34387.50	8660.89	8473.03	7702.76	770.28	187.86	3250.56	4420.52	989.80
1998	263.5	0.90	237.1	34048.20	9065.40	8881.14	8073.76	807.38	184.25	3403.09	4495.14	1167.16
1999	278.1	0.90	250.3	33702.10	9461.38	9277.58	8434.16	843.42	183.80	3550.78	4555.86	1354.74
2000	292.7	0.90	263.4	33338.60	9853.59	9658.98	8780.89	878.09	194.62	3692.36	4609.76	1551.47
2001	307.2	0.90	276.5	32951.70	10235.39	10022.76	9111.60	911.16	212.64	3826.87	4652.26	1756.26
2002	321.8	0.90	289.6	32574.40	10602.32	10378.42	9434.93	943.49	223.90	3957.95	4674.24	1970.13
2003	336.4	0.90	302.8	32328.40	11011.99	10766.92	9788.11	978.81	245.07	4101.22	4709.67	2201.10
2004	351.0	0.90	315.9	32146.41	11445.36	11170.55	10155.05	1015.50	274.81	4249.89	4748.74	2446.73
2005	–	–	–	–	12624.63	12342.16	11220.15	1122.01	282.46	4690.02	5051.03	2883.58
2006	–	–	–	–	12397.62	12094.43	10994.94	1099.49	303.19	4628.87	4932.06	2836.69
2007	–	–	–	–	12173.76	11846.70	10769.73	1076.97	327.06	4494.39	4887.22	2792.15
2008	–	–	–	–	12167.81	11833.53	10757.76	1075.78	334.27	4482.58	4880.26	2804.97
2009	–	–	–	–	12633.94	12348.77	11226.16	1122.62	285.17	4670.08	5022.60	2941.25
2010	–	–	–	–	12801.82	12465.79	11332.54	1133.25	336.02	4714.34	5118.35	2969.13
2011	–	–	–	–	13121.36	12850.86	11682.60	1168.26	270.50	4859.96	5200.56	3060.84
2012	–	–	–	–	13483.12	13312.13	12101.93	1210.19	171.00	5034.40	5278.01	3170.71
2013	–	–	–	–	13404.77	13345.16	12131.96	1213.20	59.61	5046.90	5179.30	3178.57
2014	–	–	–	–	11946.67	11850.58	10773.25	1077.33	96.09	4481.67	4642.40	2822.59
2015	–	–	–	–	11579.71	11353.65	10321.50	1032.15	226.07	4293.74	4581.74	2704.23
2016	–	–	–	–	13758.00	13712.96	12466.33	1246.63	45.04	5185.99	5305.83	3266.18
2017	–	–	–	–	11958.71	11925.55	10841.41	1084.14	33.16	4510.02	4608.24	2840.45
2018	–	–	–	–	11491.70	11285,01	10259.10	1025.91	206.69	4267.78	4536.03	2687.88
2019	–	–	–	–	13434.84	13394.35	12176.69	1217.67	40.49	5065.50	5179.05	3190.29
2020	–	–	–	–	13793.00	13718.92	12455.91	1245.59	74.07	5188.25	5337.15	3267.60
2021	–	–	–	–	13397.45	13354.50	12140.45	1214.05	42.95	5050.43	5166.22	3180.80

* – includes MSW collected from the urban territories and self-organized removal at the containers' sites and landfills from rural ones

** – includes MSW from rural territories thrown out at the dumps illegally

A3.4.2 The content of biodegradable components, DOC and MCF parameters, recycling, as well as methane emissions for MSW landfill categories in the period of 1990-2021

Year	I*	II*	III*	IV*	V*	VI*	VII*	VIII*	DOC	MCF	R**	TOTAL	Unmanaged MSW dumps, shallow	Unmanaged MSW dumps, deep	Managed MSW dumps
	Morphological structure of MSW, %								%		kt CO_2-eq.	Methane emissions from MSW dumping, kt CO_2-eq.			
1990	27.5	5.5	37.8	2.3	1.7	0.0	3.0	22.3	20.47	0.655	0.00	6534.85	1591.08	4943.76	0.00
1991	25.9	5.3	38.1	2.3	2.0	0.0	2.9	23.5	19.88	0.657	0.00	6765.19	1635.76	5115.31	14.12
1992	24.4	5.1	38.4	2.4	2.4	0.0	2.7	24.7	19.29	0.660	0.00	6953.04	1671.07	5241.86	40.10
1993	22.8	4.9	38.7	2.5	2.7	0.0	2.6	25.9	18.71	0.662	0.00	7101.03	1697.67	5327.50	75.87
1994	21.3	4.6	39.0	2.5	3.0	0.0	2.5	27.1	18.12	0.664	0.00	7210.39	1716.03	5374.89	119.46
1995	19.7	4.4	39.3	2.6	3.3	0.0	2.4	28.3	17.53	0.667	0.00	7278.76	1725.94	5384.11	168.71
1996	18.1	4.2	39.6	2.7	3.7	0.1	2.2	29.4	16.97	0.670	0.00	7309.64	1727.45	5360.66	221.53
1997	16.6	4.0	39.9	2.7	4.0	0.4	2.1	30.3	16.45	0.673	0.00	7306.50	1721.28	5308.94	276.28
1998	15.0	3.8	40.2	2.8	4.3	0.5	2.0	31.5	15.88	0.676	0.00	7318.96	1718.60	5260.87	339.50
1999	13.4	3.5	40.5	2.9	4.6	0.4	1.8	32.8	15.27	0.679	0.00	7343.51	1718.55	5214.29	410.66
2000	11.8	3.3	40.8	2.9	5.0	0.4	1.7	34.0	14.69	0.682	0.00	7376.58	1720.26	5167.23	489.09
2001	10.3	3.1	41.2	3.0	5.3	0.5	1.6	35.1	14.12	0.685	0.00	7416.36	1723.14	5119.02	574.19
2002	8.6	2.9	41.2	3.1	5.6	0.6	1.4	36.6	13.47	0.688	0.00	7460.82	1726.66	5068.85	665.30
2003	9.3	3.0	40.5	2.9	5.4	0.7	1.5	36.8	13.59	0.691	7.25	7496.75	1729.63	5013.54	753.58
2004	9.8	3.1	39.4	2.8	5.2	0.7	1.5	37.3	13.62	0.694	7.25	7557.25	1735.96	4962.84	858.45
2005	10.4	3.2	38.4	2.7	5.0	0.8	1.6	37.9	13.66	0.697	0.00	7639.24	1744.87	4915.10	979.27
2006	11.0	3.4	37.4	2.5	4.8	0.9	1.6	38.5	13.69	0.696	0.25	7765.54	1764.87	4885.98	1114.69
2007	11.6	3.5	36.4	2.4	4.5	1.0	1.7	39.0	13.75	0.698	0.00	7864.40	1780.22	4849.07	1235.11
2008	12.2	3.6	35.3	2.2	4.3	1.3	1.7	39.3	13.83	0.699	3.66	7937.90	1789.55	4810.18	1338.18
2009	12.7	3.7	34.3	2.1	4.1	1.2	1.8	40.0	13.84	0.699	54.00	7956.44	1797.24	4772.31	1386.88
2010	13.3	3.8	33.3	1.9	3.9	1.3	1.8	40.6	13.87	0.699	57.85	8035.20	1808.77	4743.13	1483.30
2011	13.7	3.9	31.8	1.8	3.6	1.3	1.9	42.0	13.72	0.699	114.16	8060.61	1819.95	4719.73	1520.93
2012	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.698	250.85	8003.23	1831.93	4697.13	1518.04
2013	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	264.37	8082.15	1848.32	4681.17	1652.47
2014	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	334.14	8094.76	1864.11	4661.16	1730.95
2015	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.698	205.90	8229.60	1863.09	4612.76	1806.69
2016	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	193.98	8232.27	1857.17	4564.91	2001.54
2017	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	409.09	8115.38	1877.06	4561.62	2085.01
2018	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.698	555.84	7972.55	1876.66	4519.46	2132.26
2019	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	632.88	7878.93	1869.73	4476.61	2165.47
2020	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	888.45	7703.23	1885.99	4473.26	2232.41
2021	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	984.75	7699.52	1904.64	4479.06	2300.57

*I - paper, II - textiles, III - food waste, IV - wood, V - garden and park waste, VI - personal care, VII - rubber and leather, VIII - non-biodegradable components

** - the total reduction in methane emissions from flaring and landfill biogas recovery

ANNEX 4 FUEL BALANCES

A4.1 Balance of natural gas

Column	Balance sheet item	Unit	2014	2015	2016	2017	2018	2019	2020	2021
1	Visible (balance) consumption. Total, including:	mln. m^3	43285.34	38008.41	36281	33781	33905	30726	31564	27130
2	- production	mln. m^3	21322.30*	20765.02*	21741*	21761*	22558*	21996*	21527*	20993
3	- imports	mln. m^3	20265.95	15584.89	13942	14051	10472	11768	9144	3137
34	- stocks change	mln. m^3	-1697.09	-1658.50	-598	2031	-875	3037	-893	-3000
5	Actual consumption. total. including:	mln. m^3	41267.56	35135.06	34153	34309	33829	31695	32873	28711
6	- Stationary Combustion	mln. m^3	35845.71*	30408.21*	29499*	30225*	31971*	27101*	28177*	24120*
7	- Mobile Combustion	mln. m^3	1398.37*	1145.11*	1400*	1944*	1802*	1861*	948*	816*
8	- Non-energy use	mln. m^3	171.41	174.87	494	407	226	124	125	152
9	- Category 2.B.1 Ammonia Production	mln. m^3	3225.98	2779.87	2153	1077	884	1731	2742	2742
10	- Natural Gas Leaks	mln. m^3	626.09	627.01	607	656	748	878	881	881
The difference between the balance sheet and actual consumption		mln. m^3	2017.78	2873.34	2128	528	-76	-969	-1309	-1581
		%	4.66%	7.56%	5.9%	1.5%	-0.22%	-3.15%	-3.98%	-5.5%

* in view of analytical study [14]

A4.2 Coal Balance

Col-umn	Balance sheet item	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Visible consumption (according to national statistics), including	kt	71571.50	71499.99	58930.96	52938.26	51905	48406	52208	49252	46052	45270
2	- mining	kt	65522.60	64203.10	48866.74*	39673.2*	33985*	28879*	31026*	30001*	26750*	24412*
3	- imports	kt	14764.24	14207.72	14694.16	14598.17	15648	19778	21387	21082	16951	19563
4	- exports	kt	6113.96	8537.28	7033.94	563.11	52	636	63	61	3	5
5	- stocks change	kt	2601.38	-1626.45	-2404.00	770.00	-2324	-385	142	1771	-2354	-1300
6	Actual consumption. total. including:	kt	75660.98	74043.46	60182.05	48451.38	56705	51468	51203	47737	43748	43035
7	- Stationary Combustion	kt	47064.28	47271.03	41602.00*	35849*	37456*	33622*	36287*	34341*	30600*	29887*
8	- Used by coke production enterprises	kt	26330.36	24154.64	17020.00	11898.00	19083	17641	14691	13394	12998	12998
9	- Non-energy use and losses	kt	2266.34	2617.79	1560.05	704.53	166	205	225	447	150	150
The difference between the balance sheet and actual consumption		kt	-4089.48	-2543.47	-1251.09	4486.88	-4800	-3062	1005	1070	2304	2235
		%	-5.71%	-3.56%	-2.12%	8.48%	-8.46%	-5.95%	1.96%	2.22%	5.00%	5.19%

* in view of analytical study [14]

A4.3 The coking coal, coke and coke gas balance

Table A4.3.1 presents the balance of coal for coking in 2021 compiled on the basis of data on the production amount (finished hard coal for coking in accordance with statistical form 1P and the analytical study [14], exports, imports as well as information on stocks of coal for coking stored by enterprises as of the beginning and end of the reporting period (according to statistical form No. 4-MTP).

Table A4.3.1. The balance of apparent consumption of coal for coking in 2021

	Production (extraction)	**Import**	**Export**	**Stocks change**	**Total consumption**
Amount, kt	2500	11484	5	-15	13994

According to coke enterprises, the humidity of the coking charge is on average approximately 10%. Thus, the charge consumption for coking calculated as the dry state was 12595 kt.

The result of the cooking process is coke, coke oven gas, coal tars and other products (Table A4.3.2).

Table A4.3.2. Yield of coke ovens in 2021, according to statistical form 1P

Indicator	**Coke. calculated as the dry weight. kt**	**Coke oven gas, kt**	**Coal tars, calculated as the anhydrous state, kt**	**Other products (benzene, ammonium sulfate, etc.), kt**
Amount	9328	1945	441	881
Yield by weight as dry-charge	74.1%	15.4%	3.5%	7.0%

Table A4.3.3 presents the coke weight balance in 2021 (in terms of dry weight) compiled on the basis of data on the production volume, imports, exports and reserves of coke in warehouses of enterprises as of the beginning and the end of the reporting period.

Table A4.3.3. Balance of coke in 2021, kt

	Production	**Import**	**Export**	**Changes in inventories**	**Total consumption on the balance**	**Actual consumption**	**Discrepancy**
Amount	9328	790	195	-42	9965	10441	-4.8%
Data source	Form 1P-NPP	Statistical data on exports/imports of products		Form 4-MTP	Estimated value	Form 4-MTP, enterprise data	Estimated value

Table A4.3.4 presents data on aggregated volumes of coke consumption by industries with an indication of the categories of the respective amounts of GHG emissions.

Table A4.3.4 coke consumption in 2021, according to statistical reporting form 4-MTP, and its accounting by CRF categories

Indicator	**The index value, kt**	**Percentage of total consumption**	**CFR category of the GHG emissions**
Total consumption	10817	100.00%	
Consumption for iron production	10327	95.5%	2.C. Iron Production. Ferroalloys Production
Other consumption	490	4.5%	

Table A4.3.5 presents aggregated data on the volumes of coke gas production and consumption by industries with an indication of the categories of the respective GHG emissions.

Table A4.3.5 Coke oven gas production and consumption in 2021, according to statistical reporting, and its accounting by CRF categories

Indicator	Index value, mln. m^3	Index value, %	CFR category of the GHG emissions
Consumption of coke oven gas for stationary combustion in coke batteries, boilers of enterprises, etc.	3685	94.6	1.A
Losses due to non-use. no account. and for other reasons	221	5.4	1.B.1.b

Comparison of the data coke oven gas production and consumption demonstrates the following: the total amount of coke oven gas consumed, taking into account the losses, is 3906 thd. m^3 which is 4.6 % differs from the amount of its production (4094 thd. m^3) taken from the form 1P.

ANNEX 5 COMPLETENESS ASSESSMENT

A5.1 Inventory of greenhouse gases

Table A5.1 shows detailed information about the categories, where notation keys were used (NE, IE) during the GHG inventory.

Table A5.1 Not estimated sources / sinks in the NIR

Sector	Gas	Category source		Notation Key	The reason for the use in the NIR
ENERGY	CO_2	1.A.3.b.ii	Light duty trucks (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.3.b.iii	Heavy duty trucks and buses (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.3.b.iv	Motorcycles (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.4.c.ii	Off-road vehicles and other machinery (gasoline, diesel oil, liquefied petroleum gases, gaseous fuels, biomass)	IE	Emissions are accounted in 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.4.c.iii	Fishing (residual fuel oil, diesel oil, gasoline, gaseous fuels, biomass)	IE	Emissions are accounted in 1.A.3.e.ii Off-road vehicles and other machinery
		1.B.1.a.1.ii	Post-Mining Activities	NE	Not considered by IPCC Guidelines
		1.B.1.a.2.i	Mining Activities	NE	Not considered by IPCC Guidelines
		1.B.1.a.2.ii	Post-Mining Activities	NE	CO_2 emissions were not estimated due to lack of the IPCC methodology
		1.B.2.a.4	Refining / Storage	NE	No IPCC methodology for calculation of CO_2 emissions
		1.B.2.a.5	Distribution of Oil Products	NE	CO_2 emissions are not estimated due to lack of IPCC default EFs
		1.B.2.c.1.ii	Gas	IE	CO_2 emissions included in 1.B.2.b.4 Transmission and storage and 1.B.2.b.5 Distribution
		1.B.2.c.1.iii	Combined	IE	CO_2 emissions included in 1.B.2.c.1.i Oil and 1.B.2.c.1.ii Gas
		1.B.2.c.2.iii	Combined	IE	CO_2 emissions included in 1.B.2.c.2.i Oil and 1.B.2.c.2.ii Gas
		1.AA	Fuel Combustion - Sectoral approach/Information item/(Biomass, Fossil fuels)	IE	Emissions are accounted in 1.A.1.a Public Electricity and Heat Production
		1.AD	Feedstocks, reductants and other non-energy use of fuels / Liquid fuels / Naphtha	IE	Emissions are accounted in 1.AD Lubricants
	CH_4	1.A.3.b.ii	Light duty trucks (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.3.b.iii	Heavy duty trucks and buses (biomass, gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, kerosene, lubricants)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.3.b.iv	Motorcycles (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.4.c.ii	Off-road vehicles and other machinery (gasoline, diesel oil, liquefied	IE	Emissions are accounted in 1.A.3.e.ii Off-road vehicles and other machinery

			petroleum gases, gaseous fuels, biomass)		
		1.A.4.c.iii	Fishing (residual fuel oil, diesel oil, gasoline, gaseous fuels, biomass)	IE	Emissions are accounted in 1.A.3.e.ii Off-road vehicles and other machinery
		1.B.2.a.5	Distribution of Oil Products	NE	Rrefinery outputs generally contain negligible amounts of methane. Consequently, methane emissions are not estimated for transporting and distributing refined products
		1.B.2.c.1.ii	Gas	IE	CH_4 emissions included in 1.B.2.b.4 Transmission and storage and 1.B.2.b.5 Distribution
		1.B.2.c.1.iii	Combined	IE	CH_4 emissions included in 1.B.2.c.1.i Oil and 1.B.2.c.1.ii Gas
		1.B.2.c.2.iii	Combined	IE	CH_4 emissions included in 1.B.2.c.2.i Oil and 1.B.2.c.2.ii Gas
		1.AA	Fuel Combustion - Sectoral approach/Information item/(Biomass, Fossil fuels)	IE	Emissions are accounted in 1.A.1.a Public Electricity and Heat Production
	N_2O	1.A.3.b.ii	Light duty trucks (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.3.b.iii	Heavy duty trucks and buses (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene, lubricants)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.3.b.iv	Motorcycles (gasoline, diesel oil, liquefied petroleum gases, other liquid fuels, biomass, kerosene)	IE	Emissions are accounted in 1.A.3.b.i Cars and 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.4.c.ii	Off-road vehicles and other machinery (gasoline, diesel oil, liquefied petroleum gases, gaseous fuels, biomass)	IE	Emissions are accounted in 1.A.3.e.ii Off-road vehicles and other machinery
		1.A.4.c.iii	Fishing (residual fuel oil, diesel oil, gasoline, gaseous fuels, biomass)	IE	Emissions are accounted in 1.A.3.e.ii Off-road vehicles and other machinery
		1.B.2.a.4	Refining / Storage	NE	No IPCC methodology for calculation of N_2O emissions
		1.B.2.c.2.iii	Combined	IE	N_2O emissions included in 1.B.2.c.2.i Oil and 1.B.2.c.2.ii Gas
		1.AA	Fuel Combustion - Sectoral approach/Information item/(Biomass, Fossil fuels)	IE	Emissions are accounted in 1.A.1.a Public Electricity and Heat Production
INDUSTRIAL PROCESSES AND PRODUCT USE	CO_2	2.B.5.a	Silicon carbide	IE	Included in 2.B.5.b Calcium Carbide
		2.C.1.d	Sinter	IE	Included in 2.C.1.b Pig Iron
		2.C.1.e	Pellet	IE	Included in 2.C.1.b Pig Iron
	CH_4	2.B.1	Ammonia Production	NE	No IPCC Metodology provided
		2.B.5.b	Calcium Carbide	NE	No IPCC Metodology provided
AGRICULTURE	CO_2	3	Sectors/Totals Agriculture Indirect emissions	NE	Indirect CO_2 emissions reported as "NE" in accordance with paragraph 37 of the UNFCCC Annex I inventory reporting guidelines
		3.G.2	Dolomite $CaMg(CO_3)_2$	NE	Dolomite used as liming material, but its number is insignificant and it is impossible to identify/calculate it
	N_2O	3.B.2	N_2O and NMVOC Emissions (Pasture, Range, and Paddock)	IE	Included in 3.D.1.3 Urine and Dung Deposited by Grazing Animals
		3.B.2.5	Indirect N_2O Emissions (N lost through leaching and run-off; Nitrogen leaching and run-off)	NE	There are no country specific factors for 2006 IPCC methodology application

		3.D.1.2.b	Sewage Sludge Applied to Soils	NE	Information about number of applied sewage sludge and other organic amendments are not available on database of SSSU and regional state agricultural departments
LAND USE, LAND-USE CHANGE AND FORESTRY	CO_2	4.A	Forest Land / 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	IE	CO_2 emissions were reported in carbon stock change reporting tables of Forest Land category
		4.B	Cropland / 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	IE	CO_2 emissions from drained organic soils are included into CSC reporting tables for Cropland Remaining Cropland
		4.B.2	Land Converted to Cropland/4(V) Biomass Burning/Wildfires	IE	Emissiona are included into Cropland remaining Cropland
		4.C	Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	IE	CO_2 emissions from drained organic soils are reported in CSC reporting tables in Grassland Remaining Grassland category
		4.D	Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Drained Organic Soils	IE	CO_2 emissions from drained organic soils on peatlands are reported in CSC reporting tables for Wetlands Remaining Wetlands
		4.D.2	Land Converted to Wetlands/4(V) Biomass Burning/Wildfires	IE	Emissions are included into Wetlands remaining Wetlands category
	CH_4	4.A	Forest Land/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	NE	There is no EF for CH_4 emissions in IPCC 2006
		4.B	Cropland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	NE	There is no EF for CH_4 emissions in IPCC 2006
		4.B.2	Land Converted to Cropland/4(V) Biomass Burning/Wildfires)	IE	Emissiona are included into Cropland remaining Cropland
		4.C	Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	NE	There is no EF for CH_4 emissions in IPCC 2006
		4.C.2	Land Converted to Grassland/4(V) Biomass Burning/Wildfires	IE	Emissions are included into Grassland remaining Grassland
		4.D.2	Land Converted to Wetlands/4(V) Biomass Burning/Wildfires	IE	Emissions are included into Wetlands remaining Wetlands category
	N_2O	4.A.2.3	Wetlands converted to forest land	NE	IPCC 2006 do not provide methods for estimation of CSC during conversions of Wetlannd to Forest Land on mineral soils
		4.B.2	Land Converted to Cropland/4(V) Biomass Burning/Wildfires	IE	Emissiona are included into Cropland remaining Cropland
		4.C.2	Land Converted to Grassland/4(V) Biomass Burning/Wildfires	IE	Emissions are included into Grassland remaining Grassland
		4.D.1	Wetlands Remaining Wetlands/4(V) Biomass Burning/Wildfires	NE	IPCC Wetlands Supplementary do not provide EF for N_2O emissions during fires on Wetlands
		4.D.2	Land Converted to Wetlands/4(V) Biomass Burning/Wildfires	IE	Emissions are included into Wetlands remaining Wetlands category
WASTE	CH_4	5.C.2.1.a	Municipal Solid Waste	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.1.b	Other (please specify)	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.2.a	Municipal Solid Waste	NE	Emissions are insignificant with accordance with Decision 24/CP.19

		5.C.2.2.b	Other (please specify)	NE	Emissions are insignificant with accordance with Decision 24/CP.19
	CO_2	5.C.2.1.a	Municipal Solid Waste	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.1.b	Other (please specify)	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.2.a	Municipal Solid Waste	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.2.b	Other (please specify)	NE	Emissions are insignificant with accordance with Decision 24/CP.19
	N_2O	5.C.2.1.a	Municipal Solid Waste	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.1.b	Other (please specify)	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.2.a	Municipal Solid Waste	NE	Emissions are insignificant with accordance with Decision 24/CP.19
		5.C.2.2.b	Other (please specify)	NE	Emissions are insignificant with accordance with Decision 24/CP.19
	NMVOC	5.C.1	Waste incineration	NE	No IPCC methodology
	NO_x	5.C.1	Waste incineration	NE	No IPCC methodology
	SO_2	5.C.1	Waste incineration	NE	No IPCC methodology
	CO	5.C.1	Waste incineration	NE	No IPCC methodology

ANNEX 6 SUPPLEMENTARY INFORMATION

A6.1 The legal framework for implementation of Ukraine's commitments under the United Nations Framework Convention on Climate Change and the Kyoto Protocol in terms of the national inventory of anthropogenic emissions and removals of greenhouse gases

##	Legal act (in the chronological order)	Links to the full text of the document
1	Law of Ukraine "On Ratification of UN Framework Convention on Climate Change" of 29.10.1996 No. 435/96-VR	http://zakon1.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=435%2F96-%E2%F0
2	Resolution of the Cabinet of Ministers of Ukraine "On the Inter-agency Committee of UNFCCC Implementation" of 14.04.1999 No.583 with amendments (Resolution of the Cabinet of Ministers of December 04, 2019 of No. 1065)	http://zakon.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=583-99-%EF
3	Law of Ukraine "On Ratification of the Kyoto Protocol for UN Framework Convention on Climate Change" of 04.02.2004 No. 1430-IV	http://zakon1.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=995_801
4	Resolution of the Cabinet of Ministers of Ukraine "On Approval of the National Action Plan for the Implementation of the Kyoto Protocol to the UN Framework Convention on Climate Change" of 18.08.2005, No. 346-r	http://zakon.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=346-2005-%F0
5	Decree of the President of Ukraine "On the Coordinator of Activities to Implement Ukraine's Commitments under the UN Framework Convention on Climate Change and Kyoto Protocol to the United Nations Framework Convention on Climate Change" of 12.09.2005 No. 1239/2005	https://zakon.rada.gov.ua/laws/show/1239/2005
6	Resolution of the Cabinet of Ministers of Ukraine "On the Coordination of Activities to Implement Ukraine's Commitments under the UN Framework Convention on Climate Change and the Kyoto Protocol to the Convention" of 10.04.2006, No. 468	http://zakon1.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=468-2006-%EF
7	Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Regulations on the National System for Estimation of Anthropogenic Emissions and Sinks of Greenhouse Gases not Regulated under Montreal Protocol on Ozone Layer Depleting Substances" of 21.04.2006, No. 554	http://zakon1.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=554-2006-%EF
8	Resolution of the Cabinet of Ministers of Ukraine "On Establishment of the National Environmental Investment Agency of Ukraine" of 04.04.2007 No. 612	http://zakon1.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=612-2007-%EF
9	Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Regulations on the National Environmental Investment Agency of Ukraine" of 30.07.2007 No. 977	http://zakon.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=977-2007-%EF
10	Resolution of the Cabinet of Ministers of Ukraine "On Ensuring Implementation of International Commitments of Ukraine under the UN Framework Convention on Climate Change and the Kyoto Protocol to It" of 17.04.2008, No. 392	http://zakon1.rada.gov.ua/cgi-bin/laws/main.cgi?nreg=392-2008-%EF
11	Resolution of the Cabinet of Ministers of Ukraine "On Optimization of the System of Central Executive Authorities" of 10.10.2014, No. 442	https://zakon.rada.gov.ua/laws/show/442-2014-п

12	Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Regulations on the Ministry of Ecology and Natural Resources" of 21.01.2015, No. 32	https://zakon.rada.gov.ua/laws/show/32-2015-п
13	Resolution of the Cabinet of Ministers of Ukraine "On Amendments to Some Regulations of the Cabinet of Ministers of Ukraine and Deeming Void Paragraph 1 of Resolution of the Cabinet of Ministers of Ukraine of July 16, 2012 No. 672" of 12.08.2015 No. 616	https://zakon.rada.gov.ua/laws/show/616-2015-п/print
14	Resolution of the Cabinet of Ministers of Ukraine "On Approving the Concept of State Climate Change Policy Implementation until 2030" of 07.12.2016 No. 932-р	https://zakon.rada.gov.ua/laws/show/932-2016-р
15	Resolution of the Cabinet of Ministers of Ukraine "On Enactment of Action Plan on Concept of State Climate Change Policy Implementation until 2030" of 06.12.2017 No. 878-р	https://zakon.rada.gov.ua/laws/show/878-2017-р
16	Resolution of the Cabinet of Ministers of Ukraine "Some Issues of Optimization of the System of Central Executive Government Bodies" of 02.09.2019 No. 829	https://zakon.rada.gov.ua/laws/show/829-2019-п
17	Resolution of the Cabinet of Ministers of Ukraine "On Amendments to Some Regulations of the Cabinet of Ministers of Ukraine" of 18.09.2019 No. 847	https://zakon.rada.gov.ua/laws/show/847-2019-п
18	Resolution of the Cabinet of Ministers of Ukraine "Some Issues of Optimization of the System of Central Executive Government Bodies" of 27.05.2020 No. 425	https://zakon.rada.gov.ua/laws/show/425-2020-п#Text
19	Resolution of the Cabinet of Ministers of Ukraine "Some Issues of Ministry of Environmental Protection and Natural Resources" of 25.06.2020 No. 614	https://zakon.rada.gov.ua/laws/show/614-2020-п#Text
20	Resolution of the Cabinet of Ministers of Ukraine "On the formation of Inter-Agency Commission of Climate Change and Ozone Layer Protection" of 23.09.2020 No. 879	https://zakon.rada.gov.ua/laws/show/879-2020-п#Text

ANNEX 7 UNCERTAINTIES

In this inventory, the uncertainty estimate is performed by using level 1 approach of the IPCC. This approach provides an estimation of uncertainty for types of emitted gases for each of the IPCC sectors. The uncertainty estimate is prepared of the inventory involves an estimating of AD uncertainties, which characterize the activity, and the uncertainty of EFs for major sources of emissions and their subsequent integrated assessment produced by combining uncertainties in accordance with the methodology set out by the 2006 IPCC Guidelines.

The results of the combined uncertainty estimate of GHG emissions (including and excluding LULUCF) reported in the Table A7.1 and Table A7.2, respectively.

The results of the combined uncertainty estimate of GHG emissions (including and excluding the LULUCF sector) for the base 1990 year reported in the Table A7.3 and Table A7.4, respectively.

Table A7.1 The results of the evaluation of the combined uncertainty of GHG emissions **including the LULUCF sector**

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2021 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2021 year, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty, %	Uncertainty in trend in national emissions introduced by activity data uncertainty, %	Uncertainty introduced into the trend in total national emissions, %
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
1	**ENERGY**												
1.A.1	Energy Industries	CO_2	271861.68	84810.85	5.32	3.18	6.20	2.37	-0.02	0.09	-0.06	0.70	0.49
		CH_4	184.29	88.03	5.32	82.43	82.60	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	635.15	336.76	5.32	324.60	324.65	0.10	0.00	0.00	0.04	0.00	0.00
1.A.2	Manufacturing Industries and Construction	CO_2	111029.98	20926.56	10.06	3.36	10.61	0.42	-0.02	0.02	-0.08	0.33	0.11
		CH_4	80.76	32.25	10.06	117.41	117.84	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	144.29	54.29	10.06	408.34	408.46	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport	CO_2	107066.83	32337.59	16.48	4.75	17.15	2.64	-0.01	0.04	-0.04	0.83	0.69
		CH_4	703.21	226.97	16.48	15.43	22.58	0.00	0.00	0.00	0.00	0.01	0.00
		N_2O	4022.81	1103.22	16.48	10.95	19.78	0.00	0.00	0.00	0.00	0.03	0.00
1.A.4	Other Sectors	CO_2	98704.92	19024.40	10.90	6.49	12.68	0.50	-0.02	0.02	-0.13	0.32	0.12
		CH_4	3009.05	24.22	10.90	98.93	99.53	0.00	0.00	0.00	-0.12	0.00	0.01
		N_2O	296.63	36.16	10.90	335.93	336.10	0.00	0.00	0.00	-0.03	0.00	0.00
1.A.5	Other (Not specified elsewhere)	CO_2	105.56	383.15	5.00	2.00	5.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	0.11	0.40	5.00	150.00	150.08	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	0.26	0.94	5.00	500.00	500.02	0.00	0.00	0.00	0.00	0.00	0.00
1.B.1	Solid Fuels	CO_2	458.73	199.18	5.48	5.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	61923.39	10968.41	14.84	5.00	15.66	0.25	-0.01	0.01	-0.07	0.25	0.07
1.B.2	Oil and Natural Gas and Other Emissions from Energy Production	CO_2	3023.81	2054.00	10.81	5.04	11.92	0.01	0.00	0.00	0.01	0.03	0.00
		CH_4	62065.54	37135.79	24.06	19.95	31.26	11.55	0.02	0.04	0.30	1.39	2.01
		N_2O	2.33	1.06	8.88	3.66	9.60	0.00	0.00	0.00	0.00	0.00	0.00

	IPCC category	Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2021 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2021 year, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty, %	Uncertainty in trend in national emissions introduced by activity data uncertainty, %	Uncertainty introduced into the trend in total national emissions, %
	A	B	C	D	E	F	G	H	I	J	K	L	M
2	**INDUSTRIAL PROCESSES AND PRODUCT USE**												
2.A.1	Cement Production	CO_2	9400.94	4338.54	1.90	5.41	5.73	0.01	0.00	0.00	0.00	0.01	0.00
2.A.2	Lime Production	CO_2	5121.81	2353.13	12.03	16.06	20.07	0.02	0.00	0.00	0.01	0.04	0.00
2.A.3	Glass Production	CO_2	187.02	283.14	6.64	2.31	7.03	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4.a	Ceramics	CO_2	111.77	48.92	2.40	5.00	5.55	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4.b	Other uses of Soda Ash	CO_2	285.84	15.33	6.00	7.00	9.22	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO_2	9798.96	3435.27	5.83	7.00	9.11	0.01	0.00	0.00	0.00	0.03	0.00
2.B.2	Nitric Acid Production	N_2O	5284.58	2407.09	3.00	5.00	5.83	0.00	0.00	0.00	0.00	0.01	0.00
2.B.3	Adipic Acid Production	N_2O	235.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.4.a	Caprolactam Production	N_2O	136.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.5	Carbide Production	CO_2	122.08	48.06	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	3.77	5.32	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00
2.B.6	Titanium Dioxide Production	CO_2	226.30	165.20	6.00	15.00	16.16	0.00	0.00	0.00	0.00	0.00	0.00
2.B.7	Soda ash production	CO_2	—	—	—	—	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.8	Petrochemical and Carbon Black Production	CO_2	1962.33	784.18	0.00	3.39	3.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	70.60	3355.52	0.00	10.00	10.00	0.01	0.00	0.00	0.04	0.00	0.00
2.C.1	Iron and Steel Production	CO_2	79689.74	36765.61	5.06	4.58	6.82	0.54	0.01	0.04	0.03	0.29	0.08
		CH_4	1117.49	533.82	5.00	20.00	20.62	0.00	0.00	0.00	0.00	0.00	0.00
2.C.2	Ferroalloys Production	CO_2	3533.41	1606.13	10.61	5.00	11.73	0.00	0.00	0.00	0.00	0.03	0.00
		CH_4	15.11	2.30	5.25	31.25	31.69	0.00	0.00	0.00	0.00	0.00	0.00
2.C.3	Aluminium Production	CO_2	170.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2021 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2021 year, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty, %	Uncertainty in trend in national emissions introduced by activity data uncertainty, %	Uncertainty introduced into the trend in total national emissions, %
	A	B	C	D	E	F	G	H	I	J	K	L	M
		PFCs	235.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C.5	Lead Production	CO_2	22.10	14.99	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00
2.C.6	Zinc Production	CO_2	24.25	1.01	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00
2.D.1	Lubricant Use	CO_2	304.83	130.76	9.00	50.09	50.89	0.00	0.00	0.00	0.00	0.00	0.00
2.D.2	Paraffin Wax Use	CO_2	122.84	10.41	6.00	100.12	100.30	0.00	0.00	0.00	0.00	0.00	0.00
2.F	Product Uses as Substitutes for Ozone Depleting Substances	HFCs	—	1901.02	55.64	34.09	65.25	0.13	0.00	0.00	0.07	0.16	0.03
2.G.1	Electrical Equipment	SF_6	0.01	48.94	34.10	18.00	38.56	0.00	0.00	0.00	0.00	0.00	0.00
2.G.3	N_2O from Product Uses	N_2O	15.31	104.71	13.63	28.25	31.37	0.00	0.00	0.00	0.00	0.00	0.00
3	**AGRICULTURE**												
3.A	Enteric Fermentation	CH_4	39311.34	7047.92	3.17	10.08	10.56	0.05	-0.01	0.01	-0.08	0.03	0.01
3.B.1	Manure management / CH_4 Emissions	CH_4	3500.97	985.31	5.59	19.13	19.93	0.00	0.00	0.00	-0.01	0.01	0.00
3.B.2	Manure management / N_2O and NMVOC Emissions	N_2O	3273.79	922.44	3.95	51.29	51.45	0.02	0.00	0.00	-0.02	0.01	0.00
3.C	Rice cultivation	CH_4	216.43	74.84	6.00	15.14	16.28	0.00	0.00	0.00	0.00	0.00	0.00
3.D.1	Direct N_2O Emissions from managed soils	N_2O	29655.98	29790.08	3.43	84.14	84.21	53.96	0.02	0.03	1.72	0.16	3.00
3.D.2	Indirect N_2O Emissions from managed soils	N_2O	8022.20	7784.96	6.39	55.90	56.26	1.64	0.01	0.01	0.29	0.08	0.09
3.G	Liming	CO_2	2592.08	176.23	6.00	50.00	50.36	0.00	0.00	0.00	-0.04	0.00	0.00
3.H	Urea application	CO_2	270.14	235.60	6.00	50.00	50.36	0.00	0.00	0.00	0.01	0.00	0.00
4	**LAND USE, LAND-USE CHANGE AND FORESTRY**												
4.A	Forest Land	CO_2	-37652.55	-33032.81	10.00	43.25	44.39	18.44	-0.02	-0.04	-0.90	-0.51	1.07
		CH_4	7.94	0.43	15.00	41.10	43.75	0.00	0.00	0.00	0.00	0.00	0.00

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2021 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2021 year, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty, %	Uncertainty in trend in national emissions introduced by activity data uncertainty, %	Uncertainty introduced into the trend in total national emissions, %
	A	B	C	D	E	F	G	H	I	J	K	L	M
		N_2O	52.86	54.43	15.00	185.02	185.63	0.00	0.00	0.00	0.01	0.00	0.00
4.B	Cropland	CO_2	-4556.78	48249.46	6.00	91.50	91.70	167.83	0.05	0.05	5.02	0.45	25.36
		CH_4	—	0.34	6.00	22.70	23.48	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	0.01	8.76	6.00	27.50	28.15	0.00	0.00	0.00	0.00	0.00	0.00
4.C	Grassland	CO_2	-946.39	92.51	6.00	330.00	330.05	0.01	0.00	0.00	0.16	0.00	0.03
		CH_4	0.13	0.16	6.00	39.10	39.56	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	0.15	0.21	6.00	47.60	47.98	0.00	0.00	0.00	0.00	0.00	0.00
4.D	Wetlands	CO_2	12232.72	240.26	10.00	30.60	32.19	0.00	0.00	0.00	-0.15	0.00	0.02
		CH_4	29.66	8.28	10.00	27.50	29.26	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4.51	1.25	10.00	36.90	38.23	0.00	0.00	0.00	0.00	0.00	0.00
4.E.2	Land converted to Settlements	CO_2	9.18	1567.48	10.00	50.00	50.99	0.05	0.00	0.00	0.09	0.02	0.01
		N_2O	0.02	99.55	10.00	50.00	50.99	0.00	0.00	0.00	0.01	0.00	0.00
4.F.2	Land converted to Other Land	CO_2	1589.43	95.69	10.00	50.00	50.99	0.00	0.00	0.00	-0.03	0.00	0.00
		N_2O	135.21	7.91	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00
4.G	Harvested Wood Products (HWP)	CO_2	-2312.91	-3163.81	13.00	29.80	32.51	0.09	0.00	0.00	-0.08	-0.06	0.01
4 (IV)	Indirect N2O Emissions from Managed Soils	N_2O	0.30	0.26	114.00	201.00	231.08	0.00	0.00	0.00	0.00	0.00	0.00
5	**WASTE**												
5.A.	Solid Waste Disposal	CH_4	6534.85	7699.52	38.36	47.27	60.87	1.88	0.01	0.01	0.27	0.46	0.28
5.B.	Biological Treatment of Solid Waste	CH_4	18.14	9.13	31.72	100.00	104.91	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	16.22	8.16	31.72	100.00	104.91	0.00	0.00	0.00	0.00	0.00	0.00

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2021 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2021 year, %	Type A sensitivity, %	Type B sensitivity, %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty, %	Uncertainty in trend in national emissions introduced by activity data uncertainty, %	Uncertainty introduced into the trend in total national emissions, %
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
5.C.	Incineration and Open Burning of Waste	CO_2	28.68	5.35	37.65	25.98	45.74	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	1.19	1.17	37.65	100.00	106.85	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4.81	5.86	37.65	100.00	106.85	0.00	0.00	0.00	0.00	0.00	0.00
5.D.1	Domestic Wastewater	CH_4	2540.62	2231.91	21.74	36.92	42.85	0.08	0.00	0.00	0.05	0.08	0.01
		N_2O	1570.15	991.73	9.41	50.38	51.25	0.02	0.00	0.00	0.02	0.01	0.00
5.D.2	Industrial Wastewater	CH_4	1601.96	1134.92	31.29	40.68	51.32	0.03	0.00	0.00	0.02	0.06	0.00
		N_2O	129.91	72.41	31.29	50.00	58.98	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL		**911401.13**	**341511.54**				**262.68**					**33.52**
						Percentage uncertainty in total inventory		**16.21**				**Trend uncertainty**	**5.79**

Table A7.2 the Results of the evaluation of the combined uncertainty of GHG emissions **excluding the LULUCF sector**

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	2021 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 2021 year. %	Type A sensitivity. %	Type B sensitivity. %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty. %	Uncertainty in trend in national emissions introduced by activity data uncertainty. %	Uncertainty introduced into the trend in total national emissions. %
A		B	C	D	E	F	G	H	I	J	K	L	M
1	**ENERGY**												
1.A.1	Energy Industries	CO_2	271861.68	84810.85	5.32	3.18	6.20	2.58	-0.01	0.09	-0.03	0.68	0.46
		CH_4	184.29	88.03	5.32	82.43	82.60	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	635.15	336.76	5.32	324.60	324.65	0.11	0.00	0.00	0.04	0.00	0.00
1.A.2	Manufacturing Industries and Construction	CO_2	111029.98	20926.56	10.06	3.36	10.61	0.46	-0.02	0.02	-0.06	0.32	0.10
		CH_4	80.76	32.25	10.06	117.41	117.84	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	144.29	54.29	10.06	408.34	408.46	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport	CO_2	107066.83	32337.59	16.48	4.75	17.15	2.87	-0.01	0.03	-0.02	0.80	0.64
		CH_4	703.21	226.97	16.48	15.43	22.58	0.00	0.00	0.00	0.00	0.01	0.00
		N_2O	4022.81	1103.22	16.48	10.95	19.78	0.00	0.00	0.00	0.00	0.03	0.00
1.A.4	Other Sectors	CO_2	98704.92	19024.40	10.90	6.49	12.68	0.54	-0.02	0.02	-0.10	0.31	0.11
		CH_4	3009.05	24.22	10.90	98.93	99.53	0.00	0.00	0.00	-0.11	0.00	0.01
		N_2O	296.63	36.16	10.90	335.93	336.10	0.00	0.00	0.00	-0.02	0.00	0.00
1.A.5	Other (Not specified else-where)	CO_2	105.56	383.15	5.00	2.00	5.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	0.11	0.40	5.00	150.00	150.08	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	0.26	0.94	5.00	500.00	500.02	0.00	0.00	0.00	0.00	0.00	0.00
1.B.1	Solid Fuels	CO_2	458.73	199.18	5.48	5.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	61923.39	10968.41	14.84	5.00	15.66	0.28	-0.01	0.01	-0.06	0.24	0.06
1.B.2	Oil and Natural Gas and Other Emissions from Energy Pro-duction	CO_2	3023.81	2054.00	10.81	5.04	11.92	0.01	0.00	0.00	0.01	0.03	0.00
		CH_4	62065.54	37135.79	24.06	19.95	31.26	12.58	0.02	0.04	0.33	1.34	1.90

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	2021 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 2021 year. %	Type A sensitivity. %	Type B sensitivity. %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty. %	Uncertainty in trend in national emissions introduced by activity data uncertainty. %	Uncertainty introduced into the trend in total national emissions. %
A		B	C	D	E	F	G	H	I	J	K	L	M
		N_2O	2.33	1.06	8.88	3.66	9.60	0.00	0.00	0.00	0.00	0.00	0.00
2	**INDUSTRIAL PROCESSES AND PRODUCT USE**												
2.A.1	Cement Production	CO_2	9400.94	4338.54	1.90	5.41	5.73	0.01	0.00	0.00	0.01	0.01	0.00
2.A.2	Lime Production	CO_2	5121.81	2353.13	12.03	16.06	20.07	0.02	0.00	0.00	0.01	0.04	0.00
2.A.3	Glass Production	CO_2	187.02	283.14	6.64	2.31	7.03	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4.a	Ceramics	CO_2	111.77	48.92	2.40	5.00	5.55	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4.b	Other uses of Soda Ash	CO_2	285.84	15.33	6.00	7.00	9.22	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO_2	9798.96	3435.27	5.83	7.00	9.11	0.01	0.00	0.00	0.00	0.03	0.00
2.B.2	Nitric Acid Production	N_2O	5284.58	2407.09	3.00	5.00	5.83	0.00	0.00	0.00	0.00	0.01	0.00
2.B.3	Adipic Acid Production	N_2O	235.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.4.a	Caprolactam Production	N_2O	136.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.5	Carbide Production	CO_2	122.08	48.06	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	3.77	5.32	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00
2.B.6	Titanium Dioxide Production	CO_2	226.30	165.20	6.00	15.00	16.16	0.00	0.00	0.00	0.00	0.00	0.00
2.B.7	Soda ash production	CO_2	—	—	—	—	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.8	Petrochemical and Carbon Black Production	CO_2	1962.33	784.18	0.00	3.39	3.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	70.60	3355.52	0.00	10.00	10.00	0.01	0.00	0.00	0.04	0.00	0.00
2.C.1	Iron and Steel Production	CO_2	79689.74	36765.61	5.06	4.58	6.82	0.59	0.01	0.04	0.04	0.28	0.08
		CH_4	1117.49	533.82	5.00	20.00	20.62	0.00	0.00	0.00	0.00	0.00	0.00
2.C.2	Ferroalloys Production	CO_2	3533.41	1606.13	10.61	5.00	11.73	0.00	0.00	0.00	0.00	0.03	0.00
		CH_4	15.11	2.30	5.25	31.25	31.69	0.00	0.00	0.00	0.00	0.00	0.00
2.C.3	Aluminium Production	CO_2	170.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		PFCs	235.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C.5	Lead Production	CO_2	22.10	14.99	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	2021 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 2021 year. %	Type A sensitivity. %	Type B sensitivity. %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty. %	Uncertainty in trend in national emissions introduced by activity data uncertainty. %	Uncertainty introduced into the trend in total national emissions. %
A		**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
2.C.6	Zinc Production	CO_2	24.25	1.01	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00
2.D.1	Lubricant Use	CO_2	304.83	130.76	9.00	50.09	50.89	0.00	0.00	0.00	0.00	0.00	0.00
2.D.2	Paraffin Wax Use	CO_2	122.84	10.41	6.00	100.12	100.30	0.00	0.00	0.00	0.00	0.00	0.00
2.F	Product Uses as Substitutes for Ozone Depleting Substances	HFCs	—	1901.02	55.64	34.09	65.25	0.14	0.00	0.00	0.07	0.16	0.03
2.G.1	Electrical Equipment	SF_6	0.01	48.94	34.10	18.00	38.56	0.00	0.00	0.00	0.00	0.00	0.00
2.G.3	N_2O from Product Uses	N_2O	15.31	104.71	13.63	28.25	31.37	0.00	0.00	0.00	0.00	0.00	0.00
3	**AGRICULTURE**												
3.A	Enteric Fermentation	CH_4	39311.34	7047.92	3.17	10.08	10.56	0.05	-0.01	0.01	-0.07	0.03	0.01
3.B.1	Manure management / CH_4 Emissions	CH_4	3500.97	985.31	5.59	19.13	19.93	0.00	0.00	0.00	0.00	0.01	0.00
3.B.2	Manure management / N_2O and NMVOC Emissions	N_2O	3273.79	922.44	3.95	51.29	51.45	0.02	0.00	0.00	-0.01	0.01	0.00
3.C	Rice cultivation	CH_4	216.43	74.84	6.00	15.14	16.28	0.00	0.00	0.00	0.00	0.00	0.00
3.D.1	Direct N_2O Emissions from managed soils	N_2O	29655.98	29790.08	3.43	84.14	84.21	58.75	0.02	0.03	1.74	0.15	3.05
3.D.2	Indirect N_2O Emissions from managed soils	N_2O	8022.20	7784.96	6.39	55.90	56.26	1.79	0.01	0.01	0.30	0.07	0.09
3.G	Liming	CO_2	2592.08	176.23	6.00	50.00	50.36	0.00	0.00	0.00	-0.04	0.00	0.00
3.H	Urea application	CO_2	270.14	235.60	6.00	50.00	50.36	0.00	0.00	0.00	0.01	0.00	0.00
5	**WASTE**												
5.A.	Solid Waste Disposal	CH_4	6534.85	7699.52	38.36	47.27	60.87	2.05	0.01	0.01	0.27	0.44	0.27
5.B.	Biological Treatment of Solid Waste	CH_4	18.14	9.13	31.72	100.00	104.91	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	16.22	8.16	31.72	100.00	104.91	0.00	0.00	0.00	0.00	0.00	0.00

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	2021 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 2021 year. %	Type A sensitivity. %	Type B sensitivity. %	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty. %	Uncertainty in trend in national emissions introduced by activity data uncertainty. %	Uncertainty introduced into the trend in total national emissions. %
A		B	C	D	E	F	G	H	I	J	K	L	M
5.C.	Incineration and Open Burning of Waste	CO_2	28.68	5.35	37.65	25.98	45.74	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	1.19	1.17	37.65	100.00	106.85	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4.81	5.86	37.65	100.00	106.85	0.00	0.00	0.00	0.00	0.00	0.00
5.D.1	Domestic Wastewater	CH_4	2540.62	2231.91	21.74	36.92	42.85	0.09	0.00	0.00	0.05	0.07	0.01
		N_2O	1570.15	991.73	9.41	50.38	51.25	0.02	0.00	0.00	0.02	0.01	0.00
5.D.2	Industrial Wastewater	CH_4	1601.96	1134.92	31.29	40.68	51.32	0.03	0.00	0.00	0.02	0.05	0.00
		N_2O	129.91	72.41	31.29	50.00	58.98	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL		**942807.63**	**327281.18**				**83.03**					**6.84**
						Percentage uncertainty in total inventory		**9.11**				**Trend uncertainty**	**2.62**

Table A7.3 The results of the evaluation of the combined uncertainty of GHG emissions **including the LULUCF sector for the base 1990 year**

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	**B**	**C**	**D**	**E**	**F**	**G**
1	**ENERGY**						
1.A.1	Energy Industries	CO_2	271861.68	0.64	2.88	2.95	0.77
		CH_4	184.29	0.64	96.70	96.70	0.00
		N_2O	635.15	0.64	364.90	364.90	0.06
1.A.2	Manufacturing Industries and Construction	CO_2	111029.98	1.85	2.68	3.26	0.16
		CH_4	80.76	1.85	86.73	86.75	0.00
		N_2O	144.29	1.85	308.53	308.54	0.00
1.A.3	Transport	CO_2	107066.83	4.48	4.57	6.40	0.57
		CH_4	703.21	4.48	15.39	16.03	0.00
		N_2O	4022.81	4.48	10.94	11.82	0.00
1.A.4	Other Sectors	CO_2	98704.92	2.35	2.82	3.67	0.16
		CH_4	3009.05	2.35	141.02	141.04	0.22
		N_2O	296.63	2.35	390.73	390.74	0.02
1.A.5	Other (Not specified elsewhere)	CO_2	105.56	5.00	2.00	5.39	0.00
		CH_4	0.11	5.00	150.00	150.08	0.00
		N_2O	0.26	5.00	500.00	500.02	0.00
1.B.1	Solid Fuels	CO_2	458.73	5.00	5.00	7.07	0.00
		CH_4	61923.39	5.00	5.00	7.07	0.23
1.B.2	Oil and Natural Gas and Other Emissions from Energy Production	CO_2	3023.81	9.42	5.00	10.66	0.00
		CH_4	62065.54	22.65	17.65	28.71	3.82
		N_2O	2.33	8.23	3.57	8.97	0.00
2	**INDUSTRIAL PROCESSES AND PRODUCT USE**						
2.A.1	Cement Production	CO_2	9400.94	1.73	5.41	5.68	0.00
2.A.2	Lime Production	CO_2	5121.81	10.04	16.06	18.94	0.01
2.A.3	Glass Production	CO_2	187.02	5.53	2.31	5.99	0.00
2.A.4.a	Ceramics	CO_2	111.77	2.00	5.00	5.39	0.00
2.A.4.b	Other uses of Soda Ash	CO_2	285.84	5.00	7.00	8.60	0.00

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	B	C	D	E	F	G
2.B.1	Ammonia Production	CO_2	9798.96	5.39	7.00	8.83	0.01
2.B.2	Nitric Acid Production	N_2O	5284.58	2.00	5.00	5.39	0.00
2.B.3	Adipic Acid Production	N_2O	235.38	2.00	10.00	10.20	0.00
2.B.4.a	Caprolactam Production	N_2O	136.27	2.00	40.00	40.05	0.00
2.B.5	Carbide Production	CO_2	122.08	5.00	10.00	11.18	0.00
		CH_4	3.77	5.00	10.00	11.18	0.00
2.B.6	Titanium Dioxide Production	CO_2	226.30	5.00	15.00	15.81	0.00
2.B.7	Soda ash production	CO_2	—	—	—	0.00	0.00
2.B.8	Petrochemical and Carbon Black Production	CO_2	1962.33	0.00	3.39	3.39	0.00
		CH_4	70.60	0.00	10.00	10.00	0.00
2.C.1	Iron and Steel Production	CO_2	79689.74	4.05	4.08	5.75	0.25
		CH_4	1117.49	5.00	20.00	20.62	0.00
2.C.2	Ferroalloys Production	CO_2	3533.41	7.07	5.00	8.66	0.00
		CH_4	15.11	5.25	31.25	31.69	0.00
2.C.3	Aluminium Production	CO_2	170.28	1.00	10.00	10.05	0.00
		PFCs	235.82	1.41	78.59	78.60	0.00
2.C.5	Lead Production	CO_2	22.10	10.00	50.00	50.99	0.00
2.C.6	Zinc Production	CO_2	24.25	10.00	50.00	50.99	0.00
2.D.1	Lubricant Use	CO_2	304.83	5.00	50.09	50.34	0.00
2.D.2	Paraffin Wax Use	CO_2	122.84	5.00	100.12	100.25	0.00
2.F	Product Uses as Substitutes for Ozone Depleting Substances	HFCs	—	—	—	0.00	0.00
2.G.1	Electrical Equipment	SF_6	0.01	33.97	22.91	40.97	0.00
2.G.3	N_2O from Product Uses	N_2O	15.31	13.63	28.25	31.37	0.00
3	**AGRICULTURE**						
3.A	Enteric Fermentation	CH_4	39311.34	2.75	11.28	11.61	0.25
3.B.1	Manure management / CH_4 Emissions	CH_4	3500.97	4.06	17.64	18.10	0.00
3.B.2	Manure management / N_2O and NMVOC Emissions	N_2O	3273.79	2.87	47.80	47.89	0.03

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	**B**	**C**	**D**	**E**	**F**	**G**
3.C	Rice cultivation	CH_4	216.43	5.00	13.45	14.35	0.00
3.D.1	Direct N_2O Emissions from managed soils	N_2O	29655.98	3.12	84.14	84.20	7.51
3.D.2	Indirect N_2O Emissions from managed soils	N_2O	8022.20	4.75	55.90	56.10	0.24
3.G	Liming	CO_2	2592.08	5.00	50.00	50.25	0.02
3.H	Urea application	CO_2	270.14	5.00	50.00	50.25	0.00
4	**LAND USE. LAND-USE CHANGE AND FORESTRY**						
4.A	Forest Land	CO_2	-37652.55	15.00	49.00	51.24	4.48
		CH_4	7.94	15.00	37.90	40.76	0.00
		N_2O	52.86	15.00	22.98	27.44	0.00
4.B	Cropland	CO_2	-4556.78	6.00	123.00	123.15	0.38
		CH_4	—	6.00	22.70	23.48	0.00
		N_2O	0.01	6.00	27.50	28.15	0.00
4.C	Grassland	CO_2	-946.39	6.00	32.80	33.34	0.00
		CH_4	0.13	6.00	39.10	39.56	0.00
		N_2O	0.15	6.00	47.60	47.98	0.00
4.D	Wetlands	CO_2	12232.72	10.00	24.50	26.46	0.13
		CH_4	29.66	10.00	27.20	28.98	0.00
		N_2O	4.51	10.00	36.70	38.04	0.00
4.E.2	Land converted to Settlements	CO_2	9.18	10.00	50.00	50.99	0.00
		N_2O	0.02	10.00	50.00	50.99	0.00
4.F.2	Land converted to Other Land	CO_2	1589.43	10.00	50.00	50.99	0.01
		N_2O	135.21	10.00	50.00	50.99	0.00
4.G	Harvested Wood Products (HWP)	CO_2	-2312.91	13.00	26.80	29.79	0.01
4 (IV)	Indirect N2O Emissions from Managed Soils	N_2O	0.30	114.00	201.00	231.08	0.00
5	**WASTE**						
5.A.	Solid Waste Disposal	CH_4	6534.85	42.43	72.46	83.96	0.36
5.B.	Biological Treatment of Solid Waste	CH_4	18.14	80.00	100.00	128.06	0.00
		N_2O	16.22	80.00	100.00	128.06	0.00

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	**B**	**C**	**D**	**E**	**F**	**G**
5.C.	Incineration and Open Burning of Waste	CO_2	28.68	80.00	40.00	89.44	0.00
		CH_4	1.19	80.00	100.00	128.06	0.00
		N_2O	4.81	80.00	100.00	128.06	0.00
5.D.1	Domestic Wastewater	CH_4	2540.62	39.05	36.92	53.74	0.02
		N_2O	1570.15	11.00	50.38	51.57	0.01
5.D.2	Industrial Wastewater	CH_4	1601.96	23.45	40.68	46.95	0.01
		N_2O	129.91	23.45	50.00	55.23	0.00
	TOTAL		**911401.13**				**19.75**
					Percentage uncertainty in total inventory		**4.44**

Table A7.4 The results of the evaluation of the combined uncertainty of GHG emissions **excluding the LULUCF sector for the base 1990 year**

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	**B**	**C**	**D**	**E**	**F**	**G**
1	**ENERGY**						
1.A.1	Energy Industries	CO_2	271861.68	0.64	2.88	2.95	0.72
		CH_4	184.29	0.64	96.70	96.70	0.00
		N_2O	635.15	0.64	364.90	364.90	0.06
1.A.2	Manufacturing Industries and Construction	CO_2	111029.98	1.85	2.68	3.26	0.15
		CH_4	80.76	1.85	86.73	86.75	0.00
		N_2O	144.29	1.85	308.53	308.54	0.00
1.A.3	Transport	CO_2	107066.83	4.48	4.57	6.40	0.53
		CH_4	703.21	4.48	15.39	16.03	0.00
		N_2O	4022.81	4.48	10.94	11.82	0.00
1.A.4	Other Sectors	CO_2	98704.92	2.35	2.82	3.67	0.15
		CH_4	3009.05	2.35	141.02	141.04	0.20
		N_2O	296.63	2.35	390.73	390.74	0.02
1.A.5	Other (Not specified elsewhere)	CO_2	105.56	5.00	2.00	5.39	0.00
		CH_4	0.11	5.00	150.00	150.08	0.00
		N_2O	0.26	5.00	500.00	500.02	0.00
1.B.1	Solid Fuels	CO_2	458.73	5.00	5.00	7.07	0.00
		CH_4	61923.39	5.00	5.00	7.07	0.22
1.B.2	Oil and Natural Gas and Other Emissions from Energy Production	CO_2	3023.81	9.42	5.00	10.66	0.00
		CH_4	62065.54	22.65	17.65	28.71	3.57
		N_2O	2.33	8.23	3.57	8.97	0.00
2	**INDUSTRIAL PROCESSES AND PRODUCT USE**						
2.A.1	Cement Production	CO_2	9400.94	1.73	5.41	5.68	0.00
2.A.2	Lime Production	CO_2	5121.81	10.04	16.06	18.94	0.01
2.A.3	Glass Production	CO_2	187.02	5.53	2.31	5.99	0.00
2.A.4.a	Ceramics	CO_2	111.77	2.00	5.00	5.39	0.00
2.A.4.b	Other uses of Soda Ash	CO_2	285.84	5.00	7.00	8.60	0.00

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	B	C	D	E	F	G
2.B.1	Ammonia Production	CO_2	9798.96	5.39	7.00	8.83	0.01
2.B.2	Nitric Acid Production	N_2O	5284.58	2.00	5.00	5.39	0.00
2.B.3	Adipic Acid Production	N_2O	235.38	2.00	10.00	10.20	0.00
2.B.4.a	Caprolactam Production	N_2O	136.27	2.00	40.00	40.05	0.00
2.B.5	Carbide Production	CO_2	122.08	5.00	10.00	11.18	0.00
		CH_4	3.77	5.00	10.00	11.18	0.00
2.B.6	Titanium Dioxide Production	CO_2	226.30	5.00	15.00	15.81	0.00
2.B.7	Soda ash production	CO_2	—	—	—	0.00	0.00
2.B.8	Petrochemical and Carbon Black Production	CO_2	1962.33	0.00	3.39	3.39	0.00
		CH_4	70.60	0.00	10.00	10.00	0.00
2.C.1	Iron and Steel Production	CO_2	79689.74	4.05	4.08	5.75	0.24
		CH_4	1117.49	5.00	20.00	20.62	0.00
2.C.2	Ferroalloys Production	CO_2	3533.41	7.07	5.00	8.66	0.00
		CH_4	15.11	5.25	31.25	31.69	0.00
2.C.3	Aluminium Production	CO_2	170.28	1.00	10.00	10.05	0.00
		PFCs	235.82	1.41	78.59	78.60	0.00
2.C.5	Lead Production	CO_2	22.10	10.00	50.00	50.99	0.00
2.C.6	Zinc Production	CO_2	24.25	10.00	50.00	50.99	0.00
2.D.1	Lubricant Use	CO_2	304.83	5.00	50.09	50.34	0.00
2.D.2	Paraffin Wax Use	CO_2	122.84	5.00	100.12	100.25	0.00
2.F	Product Uses as Substitutes for Ozone Depleting Substances	HFCs	—	—	—	0.00	0.00
2.G.1	Electrical Equipment	SF_6	0.01	33.97	22.91	40.97	0.00
2.G.3	N_2O from Product Uses	N_2O	15.31	13.63	28.25	31.37	0.00
3	**AGRICULTURE**						
3.A	Enteric Fermentation	CH_4	39311.34	2.75	11.28	11.61	0.23
3.B.1	Manure management / CH_4 Emissions	CH_4	3500.97	4.06	17.64	18.10	0.00
3.B.2	Manure management / N_2O and NMVOC Emissions	N_2O	3273.79	2.87	47.80	47.89	0.03

IPCC category		Gas	Base 1990 year emissions or removals. kt CO_2 equivalent	Activity data uncertainty. %	Emission factor / estimation parameter uncertainty. %	Combined uncertainty. %	Contribution to Variance by Category in 1990 year. %
	A	**B**	**C**	**D**	**E**	**F**	**G**
3.C	Rice cultivation	CH_4	216.43	5.00	13.45	14.35	0.00
3.D.1	Direct N_2O Emissions from managed soils	N_2O	29655.98	3.12	84.14	84.20	7.01
3.D.2	Indirect N_2O Emissions from managed soils	N_2O	8022.20	4.75	55.90	56.10	0.23
3.G	Liming	CO_2	2592.08	5.00	50.00	50.25	0.02
3.H	Urea application	CO_2	270.14	5.00	50.00	50.25	0.00
5	**WASTE**						
5.A.	Solid Waste Disposal	CH_4	6534.85	42.43	72.46	83.96	0.34
5.B.	Biological Treatment of Solid Waste	CH_4	18.14	80.00	100.00	128.06	0.00
		N_2O	16.22	80.00	100.00	128.06	0.00
5.C.	Incineration and Open Burning of Waste	CO_2	28.68	80.00	40.00	89.44	0.00
		CH_4	1.19	80.00	100.00	128.06	0.00
		N_2O	4.81	80.00	100.00	128.06	0.00
5.D.1	Domestic Wastewater	CH_4	2540.62	39.05	36.92	53.74	0.02
		N_2O	1570.15	11.00	50.38	51.57	0.01
5.D.2	Industrial Wastewater	CH_4	1601.96	23.45	40.68	46.95	0.01
		N_2O	129.91	23.45	50.00	55.23	0.00
	TOTAL		**942807.63**				**13.78**
					Percentage uncertainty in total inventory		**3.71**

ANNEX 8 INFORMATION ON IMPROVEMENTS IN THE NIR

A8.1 Consideration of the recommendations of the expert review team (ERT) presented in the Report of the individual review of the inventory submission of Ukraine submitted in 2021 (ARR 21) in the NIR

Sector	ID#	Category	Recommendation	Comment
General	G.1	Article 3.14	Report any change in the information provided under Article 3, paragraph 14, of the Kyoto Protocol, in accordance with decision 15/CMP.1 in conjunction with decision 3/CMP.11.	Information under Article 3 paragraph 14 of the KP was updated and reported in the chapter 15 compared with 2020 submission.
	G.5	National system	Submit the annual GHG inventory by 15 April each year.	As part of the inventory of greenhouse gas emissions, an annual step-by-step process planning is provided in accordance with the IPCC Guidelines for National Greenhouse Gas Inventories, 2006 (see 1.3.2 Planning and control of activities on greenhouse gas inventory and report development). For the 2020 the plan had foreseen the development and submission of Ukraine's GHG inventory submission before 15 April.
	G.7	National system	The ERT noted that a significant number of recommendations from previous UNFCCC reviews, which are associated with the LULUCF and KP-LULUCF sectors, have not been addressed by Ukraine in its 2020 and 2021 submissions. Table 3 above contains more than 20 recurring issues concerning these sectors, the majority of which are associated with fundamental elements of the sectors, such as land representation. The ERT is of the view that the accumulation of recurring issues for the LULUCF and KP-LULUCF sectors is linked to a potential problem in the national system, which appears to not be capable of collecting all the data needed to support the national LULUCF experts with the preparation of accurate and consistent time series, and significantly affects the quality of the estimated and reported emissions and removals. During the review, the Party identified lack of data and resources as the main reasons for the recurring issues. The ERT recommends that the Party prepare and report in its next annual submission an action plan detailing the steps, time frames, responsibilities, and human and financial resources required to address the issues identified in the LULUCF and KP-LULUCF sectors. The ERT also recommends that the Party report on the progress of implementation of the action plan on the LULUCF and KP-LULUCF sectors in subsequent annual submissions.	All items of the work plan were implemented. Description on how the information obtained was used in the calculations is reported in the NIR 2021 chapters 6.2.2 and 11.3.1.1. Specifically: 1) on item 1 – a working station was established and all information on forest accounting in 1988, 1996 and 2002 was scanned and processed into electronic tables; 2) on item 2 – yearly electronic databases of forest accounting from the years 2005-2014 were used in order to extract data necessary for the calculations, and processed into electronic tables; 3) on item 3 – starting from 2014 updated structure of databases was used by the Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt", thus the data were extracted in electronic tables. Implementation of this workplan allowed to collect data regularly every year, after the database is combined with separate regional databases, and checked by the specialists of the Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt".

Sector	ID#	Category	Recommendation	Comment
	G.8	Notation keys	Ukraine reported as "NE" some categories it considered insignificant in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, but it did not provide information demonstrating that the total national aggregate of estimated emissions for all gases and categories considered insignificant remains below 0.1 per cent of the national total GHG emissions. During the review, the Party explained that there were only two categories where the provision of paragraph 37(b) was used, namely category 5.C.2 open burning of waste (CO_2, CH_4 and N_2O) and category 3.B.2.5 leaching and run-off from MMS (N_2O). The justification relating to aggregated insignificant emissions being less than 0.1 per cent of total emissions will be added in the next annual submission. The ERT recommends that the Party ensure that the total national aggregate of estimated emissions for all gases and categories considered insignificant remains below 0.1 per cent of national total GHG emissions, in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, and include that information in the NIR.	The total national aggregate of estimated emissions for all gases and categories considered insignificant remains below 0.1 per cent of the national total GHG emissions. See chapter 1.7.1 Completeness assessment of GHG inventory.
	G.9	Notation keys	The Party reported in CRF table 6 indirect CO_2 emissions from atmospheric oxidation of CH_4, CO and NMVOCs as "NO" or "NA", although CH_4, CO and NMVOCs were reported for the energy, IPPU and LULUCF sectors. The ERT noted that the notation keys "NO" and "NA" are not suitable for reporting indirect CO_2 emissions because these emissions occur from the atmospheric oxidation of CH_4, CO and NMVOCs. During the review, the Party stated that the 2006 IPCC Guidelines do not provide a methodology for estimating indirect CO_2 emissions and there are no such national methodologies. For that reason, indirect CO_2 emissions are considered as not occurring in Ukraine. The ERT noted that a methodology for estimating indirect CO_2 emissions is provided in the 2006 IPCC Guidelines (vol. 1, chap. 7.2.1.5, p.7.6). In addition, according to the UNFCCC Annex I inventory reporting guidelines, Annex I Parties may report indirect CO_2 emissions from the atmospheric oxidation of CH4, CO and NMVOCs. The ERT recommends that the Party either estimate and report indirect CO_2 emissions in CRF table 6 or update the reporting of indirect CO_2 emissions in CRF table 6 by using the correct notation key (e.g. "NE") in accordance with paragraph 37 of the UNFCCC Annex I inventory reporting guidelines.	IPCC 2006 does not provide methodology for indirect CO2 emissions. Ukraine does not have any national methodologies to estimate indirect CO2 emissions. Since there are no clear guidance on indirect CO_2 emissions estimations, those are considered as not occurring in Ukraine. For LULUCF sector, NA will be changed to NO for consistency of reporting.
	G.10	Uncertainty analysis	The Party did not include in the NIR an uncertainty analysis for its base year under the Convention (1990). The ERT noted that, in accordance with paragraph 15 of the UNFCCC Annex I inventory reporting guidelines, Parties shall report uncertainties for at least the base year and the latest inventory year. During the review, the Party replied that the uncertainty analysis for the base year will be reflected in the next NIR. The ERT recommends that the Party include in the NIR an uncertainty analysis for its base year under the Convention (1990).	See chapter 1.6.1 and Annex 7.

Sector	ID#	Category	Recommendation	Comment
Energy	E.1	Fuel combustion – reference approach – solid fuels – CO_2 (E.8, 2019) Convention reporting adherence	Correct the unit (i.e. from TJ to kt) used to report solid fuels in CRF table 1.A(b).	Not resolved. The Party continued to use TJ as the unit in column D of CRF table 1.A(b), although the numerical values used for reporting production, import, export and stock change of solid fuels correspond to kt. During the review, the Party reported that the unit will be corrected, and explained that the GHG emission estimates are accurate.
	E.2	1.A Fuel combustion – sectoral approach – liquid fuels – CO_2 (E.1, 2019) (E.2, 2017) (E.8, 2016) (E.11, 2015) (31, 2014) Accuracy	Develop and use country-specific CO_2 EFs for liquid fuels (i.e. residual fuel, diesel oil, LPG, petroleum coke and refinery gases), which have a significant share in the fuel mix of stationary combustion.	Addressing. The Party reported in the NIR (chap. A2.4.1, p.332) that when calculating the volume of GHG emissions at stationary combustion, motor fuels in CRF category 1.A.1 "Energy Industries" were not transferred to other sources of emissions; in categories 1.A.2 "Manufacturing Industries and Construction" and 1.A.4 "Other Sectors" motor fuels (gasoline, gas oil, etc, for the exception of liquefied propane and butane) were not accounted for the period of 1991–2019 and were transferred to the category of mobile sources - CRF 1.A.3 "Transport", because no information is available for the period on their use in stationary combustion. The Party reported in its NIR (chap. A2.6.3, p.347) that methodological recommendations for determining country-specific CO_2 EFs from motor fuels in the transport sector were developed following research undertaken in 2017, which were used for the 2021 submission. According to Ukraine, the carbon content and net calorific value for gasoline, diesel oil and LPG (see NIR table A2.4) consumed were determined for 2014, while retrospective values were obtained for the entire time series. The Party reported that data for 2015–2019 were based on 2014 data. The ERT considers that the recommendation has not yet been fully addressed because country-specific CO_2 EFs for residual fuel and petroleum coke have not been developed.
	E.4	1.A.3.b Road transportation – LPG – CO_2, CH_4 and N_2O (E.11, 2019) Consistency	Demonstrate that the use of different data sources for 1990–2015 and 2016 onward result in consistent CO_2, CH_4 and N_2O emission estimates across the time series.	Addressing. The Party reported in its NIR (chap. 3.2.9.2.2, p.84) that emissions for the category for the entire time series were calculated using data on energy use of fuels according to

Sector	ID#	Category	Recommendation	Comment
				statistical form 4-MTP, taking into account the analytical study (see reference 26 in NIR p.311) using the balance sheet method and the national carbon content coefficients for gasoline, diesel and LPG, which correspond to tier 2 for CO_2 emissions and tier 1 for other gases. However, the ERT considers that the recommendation has not yet been fully addressed because the explanation provided does not detail how consistency is maintained across the time series. During the review, the Party explained that calculations were conducted using the surrogate method presented in the 2006 IPCC Guidelines (vol. 1, chap. 5, equation 5.2) on the basis of 2015 data as stated in the NIR (chap. 3.2.9.2.2, p.84). IEA LPG activity data were used to derive a proxy used in the calculations: surrogate statistical parameters in year 0 and t (as referred to in equation 5.2).
	E.5	1.A.3.d Domestic navigation – liquid fuels – CO_2 (E.4, 2019) (E.23, 2017) Transparency	Include in the NIR documentation of the observed trends in cargo for national and international navigation, particularly for 2012 onward.	Addressing. The Party reported in its NIR (figures A.21–A.22, pp.334–335) on the observed trends in cargo for domestic and international navigation. The ERT noted the Party's explanation in the 2019 review that water transport plays a role in reserve infrastructure and, because water levels in rivers in Ukraine are decreasing every year, significant fluctuations in navigation may be seen, and that increases in 2015 were due to the substitution of railway and road transportation as a result of national circumstances and fluctuations in the national economy (see document FCCC/ARR/2019/UKR, ID# E.4). These explanations are however not included in the NIR.
	E.9	1.B.1.c Other (solid fuels) – solid fuels – CO_2 and CH_4 (E.13, 2019) Transparency	Improve the information on allocation of CH4 emissions from coal bed CH_4 flaring.	Addressing. The Party reported in its NIR (chap. 3.3.1.4, p.93) that CH_4 emissions associated with coal bed CH4 flaring (reported under CRF category 1.B.1.c) in 2012–2019 were estimated using the surrogate method from the 2006 IPCC Guidelines on the basis of equation 1.4.5 and the 2012 AD reported in NIR table 3.15 p.94. During the review, the Party clarified that it

Sector	ID#	Category	Recommendation	Comment
				used equation 5.2 (2006 IPCC Guidelines, vol. 2, chap. 5) and therefore the reference to equation 1.4.5 was an error. The Party committed to correcting the text in the NIR (chap. 3.3.1.4) for its next submission.
	E.10	1.B.1.c Other (solid fuels) – solid fuels – CO_2 and CH_4 (E.13, 2019) Transparency	Investigate whether double counting now occurs for coal bed CH_4 flaring between categories 1.B.1.c and 1.A.1.c (i.e. clarify whether the flaring emissions reported under category 1.A.1.c in the 2017 submission were removed from category 1.A.1.c with the reporting of flaring under category 1.B.1.c) and report in the NIR on the findings.	Not resolved. The NIR did not contain any information explaining that the emissions are not covered under 1.A.1.c. In the NIR (annex 8, p.540) the Party stated that no response is required to the recommendation from the previous review report. During the review, the Party explained that there is no double counting for coal bed CH_4 flaring between categories 1.B.1.c and 1.A.1.c. The ERT considers that the recommendation has not yet been fully addressed and that the findings of the investigation on the possible double counting need to be reported in the next NIR.
	E.11	1.B.2.a Oil – CO_2, CH_4 and N_2O (E.7, 2019) (E.25, 2017) Transparency	Include an explanation in the NIR for the choice of CO_2, CH_4 and N_2O EFs for estimating emissions for the oil category, including documentation of the current state of oil industry infrastructure.	Addressing. The Party reported in its NIR (chap. 3.3.2.1, p.95) that six refineries operational in Ukraine up to 2009 had stopped operations by 2012. Currently, only one refinery is working, for which the information on crude oil refined is confidential, hence the use of default EFs. The ERT considers that the recommendation has not yet been fully addressed because information on the current state of the oil industry infrastructure (technology employed) was not provided.
	E.12	1.B.2.a Oil (E.14, 2019) Transparency	Include in the NIR the information that a large quantity of oil transits through the country (i.e. it is not sourced from Ukraine and not transformed or used in Ukraine) and that oil is transported only by pipeline and not by any other sources mentioned in the 2006 IPCC Guidelines.	Addressing. The Party reported in its NIR (chap. 3.3.2.1, pp.95–96) that oil transportation in Ukraine is carried out only by pipeline, whereby 13,127 kt oil transited through the country and 2,382 kt oil was transported by pipeline for the Addressing. country's own use in 2019. The oil pipeline system includes 19 pipelines up to 1,220 mm in diameter with a total length of 3,507 km, 28 oil pumping stations (176 stations units), 79 in-service tanks and an offshore oil terminal "Yuzhny". Input system capacity is 114 Mt/year, with an output of 56.3 Mt/year. The Party further reported in the NIR (chap. 3.3.2.1.2, p.96) that default EFs for transportation of oil by pipeline were used in

Sector	ID#	Category	Recommendation	Comment
				accordance with the 2006 IPCC Guidelines (vol. 2, section 4.2.2.3). In the NIR (chap. 3.3.2.1.2, p.96) the Party stated that, since the volume of oil transited through the territory of Ukraine is considerably higher than its local production volume, the conversion of the amount of transported oil from mass units used by oil transportation enterprises into volumetric units was conducted using the average density of the Russian Urals export blend (0.865 t/m3). During the review, the Party referred to the information reported in the NIR. The ERT considers that the recommendation has not yet been fully addressed because information on whether there are any other means of transportation of oil has not been included.
	E.14	1.B.2.b Natural gas – CO_2 and CH_4 (E.16, 2019) Transparency	Improve the transparency of reporting for this category by including in the NIR the explanation for the decreasing trend observed in the natural gas transmission (compared with production increases) that was provided during the review.	Not resolved. There is no information explaining the trend added in the NIR. During the review, the Party explained that the natural gas transmission and production trends are independent because of the sizeable amount of transit gas (see CRF table 1.B.2).
	E.15	1.B.2.b Natural gas – CO_2 and CH_4 (E.18, 2019) Accuracy	Revise emission estimates for the exploration, production and processing of natural gas using a tier that is in accordance with the 2006 IPCC Guidelines (vol. 2, figure 4.2.1).	Not resolved. In the NIR (chap. 3.3.2.2, p.98), the Party indicated that it used tier 1 default CO_2 and CH_4 EFs to estimate emissions from exploration, production and processing of natural gas. During the review, the Party explained that no country-specific CO_2 and CH_4 EFs have been developed and there are no AD for applying higher-tier methods for this category.
	E.16	1.B.2.b Natural gas – CO_2 and CH_4 (E.18, 2019 Accuracy	Develop a category-specific improvement plan, detailing the plan in the NIR.	Not resolved. In the NIR (chap. 3.3.2.7, p.100), the Party indicated that no category-specific improvements are planned. During the review, the Party reported that it will address this recommendation as soon as financing is allocated for the improvement.
	E.17	1.B.2.c Venting and flaring – all gases (E.19, 2019) Transparency	Enhance the transparency of the plans to improve the national inventory by including a detailed description of the planned improvement for estimating natural gas venting emissions.	Not resolved. In the NIR (chap. 3.3.2.7, p.100), the Party indicated that no category-specific improvements are planned. During the review, the Party reported that this recommendation will be addressed as soon as financing

Sector	ID#	Category	Recommendation	Comment
IPPU	I.7	2. General (IPPU)	The Party reported "NO" in CRF tables 2(I)s1, 2(I)s2, 2(II), 2(II)B-Hs1 and 2(II)B-Hs2 for AD and emissions for all relevant gases under categories 2.B.9 fluorochemical production and 2.G.2 SF6 and PFCs from other product uses, but did not provide any explanation in the NIR for the absence of these AD and emissions. During the review, the Party clarified that the activities under categories 2.B.9 and 2.G.2 do not occur in the country and that it will include this information in the next NIR. The ERT recommends that the Party improve the transparency of the information reported by including in its NIR a dedicated section on categories 2.B.9 fluorochemical production and 2.G.2 SF6 and PFCs from other product uses, documenting the absence of the AD and emissions for these categories.	Taken into account. Please see relevant section 4.3.9 Fluorochemical Production (CRF category 2.B.9) and SF6 and PFCs from Other Product Uses (CRF category 2.G.2) respectively.
	I.8	2. General (IPPU)	The Party reported in its NIR (tables A.3.1.1.3 and A.3.1.1.8, pp.369–370 and 375) the AD for categories 2.A.2 and 2.B.2 for the entire time series. The ERT noted that the inter-annual changes in AD for 2.B.2 nitric acid production are significant for 2006/2007 (30.3 per cent), 2008/2009 (31.6 per cent), 2010/2011 (28.6 per cent), 2012/2013 (23.4 per cent), 2017/2018 (9.6 per cent) and 2018/2019 (52.8 per cent); and the inter-annual changes in AD for category 2.A.2 lime production are significant for 1990/1991 (11.9 per cent), 2010/2011 (18.5 per cent) and 2013/2014 (20.6 per cent). During the review, the Party clarified that the inter-annual changes in AD were due mainly to economic factors (increase in consumption of feedstock, global financial and economic crisis, etc.). The ERT agreed that the explanation provided could clarify the trend in the production of lime and nitric acid in the country. The ERT recommends that the Party provide in the NIR an explanation of the observed trends in AD and the drivers behind the significant inter-annual changes for key categories 2.B.2 nitric acid production and 2.A.2 lime production.	Taken into account. Please see relevant sections 4.2.2 Lime Production (CRF category 2.A.2)/ 4.2.2.1 Category description and 4.3.2 Nitric Acid Production (CRF category 2.B.2)/ 4.3.2.1 Category description respectively.
	I.9	2.A.1 Cement production – CO_2	The Party reported in its NIR (chap. 4.2, p.104) that the tier 2 method was used to calculate CO_2 emissions for category 2.A.2 cement production. The Party also reported in the NIR (chap. 4.2, pp.103–105) that the CO2 EF was calculated taking into account the plant-specific data on the content of CaO in clinker. The Party clarified in the NIR that in 2012–2019 the share of CaO derived from a non-carbonate source decreased but no information on the share of CaO from a non-carbonate source (e.g. steel slag or fly ash) or the MgO content in clinker was provided in the NIR. In the NIR (chap. 4.2.5, p.105) Ukraine reported that the recalculations of CO2 emissions were made for 2018 because of updates to the data for the CaO and MgO content in clinker. However, from the explanation in the NIR it is not clear how the CO_2 EFs were derived. According to the 2006 IPCC Guidelines (vol. 3, chap. 2.2.1.2, p.2.12) the derivation of a CO_2 EF for clinker requires the CaO content of the clinker to be known, as well as the fraction of CaO that was derived from a carbonate source (generally calcium carbonate). During the review, the	Taken into account. Please see relevant sections 4.2.1 Cement Production (CRF category 2.A.1)/ 4.2.1.1 Category description (Table 4.2. The basic data on the results of GHG inventory in cement production in 2020) and 4.2.1.2 Methodological issues. The annual plant-specific CaO, MgO content in clinker and the share of CaO derived from a non-carbonate source content for the whole time series please see in Annex 3/ A3.1 Industrial Processes and Product Use (CRF Sector 2)/ Table A3.1.1.2 Greenhouse gas emissions from Cement Production (CRF category 2.A.1).

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			Party provided the ERT with the annual plant-specific CaO content (66.1 percent) for 2019. It explained that the non-carbonate sources for clinker production were not used in 2019 and that the MgO content in clinker was taken into account to determine the EF. The ERT recommends that the Party include in the NIR information on the annual plant-specific CaO content for the whole time series and an explanation of how the national CO_2 EF for clinker was derived, including information on the MgO content in clinker and the share of CaO derived from a non-carbonate source.	
	I.10	2.B.2 Nitric acid production – N_2O	The Party reported in its NIR (chap. 4.7, pp.113–114) that N2O emissions for category 2.B.2 nitric acid production were estimated using tier 2 and 3 methods. The ERT agreed with the estimation of emissions for enterprises with low-pressure units using tier 2. At the same time, the Party reported in its NIR (table 4.11, p.114) that the emissions for medium-pressure units were estimated using tier 3 for the whole time series, while the default N_2O EF (7 kg/t) (2006 IPCC Guidelines, vol. 3, part 1, table 3.3, p.3.23) was used for 1990–2008. Moreover, in NIR table A3.1.1.8, the default N_2O EF (7 kg/t) for 1990–2008 was defined as country-specific. During the review, the Party clarified that in 2009 direct test measurements were performed on the recommendation of the Ukrainian Chemists Union to define the country-specific N_2O EF for units of medium pressure. However, the justification that the applied default N_2O EF for 1990–2008 is country-specific was not provided. This is not in accordance with the 2006 IPCC Guidelines (vol. 3, chap. 3.3.2) because the tier 3 method requires real measurement data and plant-level EFs obtained from direct measurement of emissions. It was not explained in the NIR how the N_2O EF value for 1990–2008 was derived and how time-series consistency was ensured. The ERT recommends that Ukraine ensure the time-series consistency of the estimates of N_2O emissions from nitric acid production for medium-pressure units by using the methods suggested in the 2006 IPCC Guidelines (vol. 1, chap. 2.2.4, pp.2.12–2.16). The ERT also recommends that the Party report the N_2O EFs used across the time series for estimated emissions for medium-pressure units if they are not all based on measured data.	Taken into account. Please see relevant sections 4.3.2 Nitric Acid Production (CRF category 2.B.2)/ 4.3.2.1 Category description (Table 4.10. The basic data on the results of GHG inventory in nitric acid production in 2020 and 4.3.2.2 Methodological issues. The annual N_2O EFs used across the time series for estimated emissions please see in Annex 3/ A3.1 Industrial Processes and Product Use (CRF Sector 2)/ Table A3.1.1.8 Greenhouse gas emissions from Nitric Acid Production.
	I.11	2.B.8 Petrochemical and carbon black production – CO_2 and CH_4	The Party reported in its NIR (annex 3, table A3.1.1.10, pp.377–378) the EFs used to estimate CO_2 and CH_4 emissions and corresponding emissions for category 2.B.8. The Party applied a CH_4 EF of 28.7 kg/t carbon black produced to estimate emissions for category 2.B.8.f carbon black, while in the NIR (chap. 4.13.2, p.121) it is stated that the default parameters were used. The ERT noted that whereas the value used is the default CH_4 EF for carbon black production without thermal treatment in the 2006 IPCC Guidelines (vol. 3, table 3.24, p.3.80), the default process is thermal treatment, so the default CH_4 EF of 0.06 kg/t carbon black produced should be used. Moreover, there was	Taken into account. The estimation of CH_4 emissions from carbon black production was performed with using CH_4 EF of 0.06 kg/t carbon black produced. Please see relevant sections 4.3.8. Petrochemical and Carbon Black Production (CRF category 2.B.8)/ 4.3.8.2 Methodological issues and 4.3.8.5 Category-specific recalculations as well as Annex 3/ A3.1 Industrial Processes and Product

Sector	ID#	Category	Recommendation	Comment
			not enough information on the production processes of carbon black, methanol and VCM to justify the EF used. In addition, the Party reported in the NIR (p.119) that methanol is obtained from CO and hydrogen in the presence of catalysts, and in dry distillation of wood. At the same time, the Party used the IPCC default CO_2 EF of 0.67 t CO_2/t methanol produced, which is used for natural gas as a feedstock and conventional steam reforming without primary reformer as a default process (2006 IPCC Guidelines, vol. 3, part 1, table 3.12, p.3.73). During the review, the Party clarified that, according to the data obtained from enterprises, carbon black was produced using the furnace black process, methanol was produced using conventional steam reforming without primary reformer and VCM was produced using a balanced process for ethylene dichloride production integrated with VCM production plant. A tier 1 methodology and default EFs were used to calculate CO_2 and CH_4 emissions from carbon black, methanol and VCM processes. The ERT recommends that the Party use the CH_4 EF of 0.06 kg/t carbon black produced that is provided in the 2006 IPCC Guidelines (vol. 3, table 3.24, p.3.80) for the default process or justify the use of the CH_4 EF of 28.7 kg/t carbon black produced for estimating CH_4 emissions for category 2.B.8.f carbon black. The ERT also recommends that the Party provide a transparent description of the production processes and feedstock used for the production of carbon black, methanol and VCM and, if necessary, correct the parameters used in accordance with the 2006 IPCC Guidelines (vol. 3, chap. 3.9.2.2).	Use (CRF Sector 2)/ Table A3.1.1.10 Greenhouse gas emissions from Petrochemical Production. A transparent description of the production processes and feedstock used for the production of carbon black, methanol and VCM was corrected please see relevant sections 4.3.8. Petrochemical and Carbon Black Production (CRF category 2.B.8)/ 4.3.8.1 Category description.
	I.12	2.D.1 Lubricant use – CO_2	The Party reported in the NIR (chap. 4.20.1, p.130) that it used AD from IEA for 1990–1997, data from SSSU for 1998–2017 and data from national research for 2014–2019 to estimate CO2 emissions. The ERT noted that these data sets are by no means consistent as each uses a different set of assumptions to derive the data. The ERT also noted that the inter-annual changes in AD values for 1995/1996 (119.9 per cent), 1996/1997 (17.9 per cent), 1997/1998 (–28.8 per cent) and 2006/2007 (22.7 per cent) seem to be outliers and need to be checked by the Party. During the review, the Party clarified that a misprint occurred and that the data obtained from SSSU (form 4-MTP) for lubricant non-energy consumption were used for 1998–2019 and the data from IEA questionnaires were used for 1990–1997; and that IEA also uses data sources from form 4-MTP. National research data for 2014–2019 were used only for the revision carried out to account for amounts of lubricant consumption in temporarily occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and parts of the Donetsk and Luhansk regions. The Party explained that the significant changes in lubricant use for 1996, 1997 and 1998 are a result of lubricants being imported to Ukraine since 1996, and the changes in 2007 are due to a sharp growth in the production and importation of lubricants in Ukraine. The ERT recommends that the Party ensure the time-series consistency of its emission estimates by applying the same data source for the entire time series,	Taken into account. The estimation of CO_2 emissions from lubricant use was performed in accordance with data from IEA questionnaires for the whole time series, please see relevant sections 4.5.1 Lubricant Use (CRF category 2.D.1)/ 4.5.1.2 Methodological issues and 4.5.1.5 Category-specific recalculations as well as Annex 3/ A3.1 Industrial Processes and Product Use (CRF Sector 2)/ Table A3.1.1.15 Greenhouse gas emissions from Lubricant Use. The explanation about inter-annual changes in lubricant use for 1996, 1997, 1998 and 2007 please see in relevant sections 4.5.1 Lubricant Use (CRF category 2.D.1)/ 4.5.1.1 Category description.

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			or, if this is not possible, apply a splicing technique from the 2006 IPCC Guidelines (vol.1, chap. 5.3.3) or provide the supporting information that the IEA and SSSU data sets use the same source. The ERT also recommends that the Party include the information provided during the review to explain the significant inter-annual changes in lubricant use over the time series (e.g. for 1996, 1997, 1998 and 2007) in the next NIR.	
Agriculture	A.1	General (agriculture) – CO_2, CH_4 and N_2O (A.2, 2019) (A.17, 2017) Convention reporting adherence	Improve the QC checks to ensure that all tables referred to in the text of the NIR actually exist in the NIR and contain the information stated.	This issue considered and the text has been corrected. Appropriate annual measures for detection of inconsistencies and errors are held in accordance with a plan of QA/QC procedures. Information about (1) "Crude protein content in all kinds of cattle fodders" and (2) "Dairy cows milk production and fat content" reported in Annex 3.2 (tables A3.2.3.7 and A3.2.2.6 respectively). This is an error that Table A3.2.2.6 contains milk protein data (this table containe only "milk production" and "fat content" data that used for relevant estimations).
	A.3	3.B.1 Cattle 3.B.3 Swine – CH_4 (A.12, 2019) (A.10, 2017) (A.23, 2016) Transparency	Include in the NIR relevant information on the reported MMS (e.g. how manure is handled (1), mechanically separated (2) and stored (3), and the emptying frequencies (4) of the lagoons/manure stores and field application) (the description should include a mass balance (5) for all handled manure based on excreted VS (6) in each MMS and indicate whether or not the manure is covered by a crusting layer (7)).	This issue considered and relevant data reports in Chapter 5.3.2.1 Methane emissions from Manure Management (part "Manure management system"). (1) In accordance with "Departmental standards of technological design of livestock MMS operating on the farms and complexes" [11, 14, 16] type of manure handleding (mechanical or hydraulic) are determined by the specification of manure management system (see Table 5.11, Chapter 5.3.2.1). (2) Mechanical separation is not typical for manure management such as litter-free technology provides, that any feeding waste don't mix with manure (see notes for Table 5.11, Chapter 5.3.2.1). (3) Manure storing determined by the specification of manure management system in accordance with "Departmental

Sector	ID#	Category	Recommendation	Comment
				standards of technological design of livestock MMS operating on the farms and complexes" [11, 14, 16]. Solid and liquid systems, composting, and pasture/range/paddock are typical for cattle manure managing at agrienterprises. Manure stored in unconfined piles or stacks for a several months processed in solid systems. That manure fraction, which stored as excreted or with some minimal addition of water in either tanks or earthen ponds without mixing, is processed in liquid systems. Swine manure at agrienterprises managed in solid and liquid systems, by composting and aerobic treatment or uncovered anaerobic lagoons. Manure in households is kept exclusively in clamps with litter (straw, sawdust, peat), or remains in paddocks. (4) There are different storaging period of hydraulicly handled manure. According to relevant MMS specialization hydraulicly handled manure distributed to liquid systems or lagoons (aerobic treatment and uncovered anaerobic lagoons). (5) For GHG estimation in 3.B used data of MMS rate. Rate of handled manure that distributed by the manure management systems reported in Annex 3.2.3, Table A3.2.3.2. (6) The amount of volatile dry substances (VS), which emitted from the cattle and sheep manure, calculated according to Equation 10.24 [1]. For swine and poultry, this factor obtained with Equation 5.1 of current NIR (see Chapter 5.3.2.1 Methane emissions from Manure Management). Relevant VS data reported in Annex 3.2.3, Table A3.2.3.3. (7) Hydraulicly handled manure stored with natural crust covering. Relevant MCF values that used in these cases reported in Table 5.10 (Chapter 5.3.2.1).

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	A.6	3.G Liming – CO_2 (A.21, 2019) (A.31, 2017) Transparency	Conduct an assessment of the proportion of inert materials in ground lime and document the results in the NIR; and, if ground lime is considered to include inert materials, revise the CO_2 emissions for the entire time series, excluding the portion of the inert materials in ground lime.	In accordance with the letters from National Academy of Agrarian Sciences of Ukraine (№12881/5/20 of 28.08.2020 and №30016/10/21 of 15.07.2021) improving the quality of acidic soils in Ukraine is carried out by their liming with lime fertilizers. The raw materials for the lime fertilizers production are natural limestone rocks and industrial waste. Natural limestone rocks are represented by hard (limestone, dolomite, chalk) and soft (calc-sinter, marl, clay marl, powder dolomite) rocks. Also used products of processing of natural limestone rocks – quicklime and slaked lime. As a raw for the lime fertilizers production used some kinds of industrial waste, which contain Ca^{+2} and Mg^{+2}, such as defecation dirt, shale and peat ash, cement kiln dust, ets. Sources of data on liming materials (lime fertilizers) that applied to acidic agricultural soils were Statistical bulletin: "The application of synthetic and organic fertilizers for harvest of agricultural crops" and analytical study. For those years where statistics are not available, the interpolation method used. However, national statistics do not collect a data about kinds of liming fertilizers that used for liming acidic agricultural soils (collected data only in full weight of lime materials). So, information about actual kinds of liming fertilizers, their number, which was applied, and content of inert materials in them are not available for all report period. Two conservative judgments were made according to country specific practices of lime fertilizers application and evaluation of inert materials content in them: – limestone fertilizers contain not less than 85 % of the active substance [19-20] and this coefficient used for estimation the amount of liming materials in weight of active matter; – dolomite used as liming material, but its number is insignificant and it is impossible to identify/calculate it.

Sector	ID#	Category	Recommendation	Comment
				As the liming is performed by introduction of liming fertilizers that mostly contain $CaCO_3$, it was decided to use the default emission factor from the 2006 IPCC Guidelines to evaluate CO_2 emissions from liming, which is 0.12. AD detailing and EF clarification are the main improvements in this category.
	A.7	3.B Manure management – CH_4	The ERT encourages the Party to report in its NIR, in the section on category-specific planned improvements, the timeline for a study on distribution of cattle and swine manure and MMS determination.	Relevant improvements and their description are reported in Chapter 5.3.6 "Category-specific planned improvements".
	A.8	3.B.3 Swine – CH_4	The ERT recommends that the Party revise the allocation per MMS for swine in CRF table 3.B(a)s2.	The allocation per MMS for swine in CRF table 3.B(a)s2 are revised.
	A.9	3.D.a.2.b Sewage sludge applied to soils – N_2O	The ERT recommends that the Party clearly justify in the NIR why the emissions from the use of sewage sludge as organic fertilizer are considered to be insignificant and use notation key "NE" in CRF table 3.D in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.	Notation key "NE" used in CRF table "3.D.1.2.b Sewage Sludge Applied to Soils" in accordance with current ERT recommendation. Information about number of applied sewage sludge and other organic amendments are not available on database of SSSU and regional state agricultural departments. The issue of sewage sludge and other organic amendments using as an alternative type of organic fertilizer studies in the scientific articles. However, information about these studies' recommendations implementation is not available. In the Waste sector sewage sludge mostly dried and storage on the sludge-drying beds. Special attention is paid to this issue and it is planned to collect more data and improve it.
	A.10	3.G Liming – CO_2	The ERT recommends that the Party include information in the NIR in order to justify the decision to not estimate emissions from this source (1), and report emissions for this category as "NE" in CRF table 3.G-I in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines (2).	(1) National statistics do not collect a data about kinds of liming fertilizers that used for liming acidic agricultural soils (collected data only in full weight of lime materials). So, information about actual kinds of liming fertilizers, their number, which was applied, and content of inert materials in them are not available for all report period.

Sector	ID#	Category	Recommendation	Comment
				That is why two conservative judgments were made according to country specific practices of lime fertilizers application and evaluation of inert materials content in them: – limestone fertilizers contain not less than 85 % of the active substance [19-20] and this coefficient used for estimation the amount of liming materials in weight of active matter; – dolomite used as liming material, but its number is insignificant and it is impossible to identify/calculate it. As the liming is performed by introduction of liming fertilizers that mostly contain $CaCO_3$, it was decided to use the default emission factor from the 2006 IPCC Guidelines to evaluate CO_2 emissions from liming, which is 0.12. AD detailing and EF clarification are the main improvements in this category. (2) Notation key "NE" used in CRF table "3.G.2 Dolomite $CaMg(CO_3)_2$" in accordance with current ERT recommendation.
	A.11	3.H Urea application – CO_2	The ERT recommends that the Party revise the AD used for the estimation of emissions for this category to ensure consistency across the time series, in particular the approach used to fill the gaps for the years for which no information is available from national sources or FAOSTAT, to ensure that there is no underestimation of emissions (1). The ERT also recommends that the Party make sure that national data sources cover all uses of urea on soils under the agriculture sector, in particular for uncultivated grasslands, and update the emission estimates for categories 3.H and 3.D accordingly (2).	(1) The main sources of data are the SSSU and analytical study [2]. However, SSSU do not collect a data of amount of urea that used as a fertilizer on agricultural soils during the 1990-2017 period (the statistical bulletin "The application of synthetic and organic fertilizers for harvest of agricultural crops" [24] contains this data from 2018). Therefore, alternative sources of data (FAO (http://faostat3.fao.org/download/R/RF/E), conservative judgement) used for AD collection. AD sources ranged in the next line: *Maine source* ⇒ *Alternative sources* or *SSSU* ⇒ *FAO* ⇒ *Conservative judgement* That is why for reporting period AD collected from different sources: – 1990-2001 – as a share (conservative coefficient according to country specific

Sector	ID#	Category	Recommendation	Comment
				practice) of the total annual number of the applied N fertilizers; – 2002-2004 – FAO data; – 2005-2007 – as a share (conservative coefficient according to country specific practice) of the total annual number of the applied N fertilizers; – 2008-2011 – FAO data; – 2012-2017 – interpolation and analytical study [2] (analytical study used since 2014); – 2018-onwards – SSSU data and analytical study [2]. Analysis of AD sources show that for 1990-2017 used only alternative sources. However, for 1990-2017 period FAO reported data only for 2002-2004 and 2008-2011. For 1990-2001 and 2005-2007 the data of applied urea calculated as a share of the total annual number of the applied N fertilizers. This factor (a share of the total annual number of the applied N fertilizers) estimated as conservative coefficient according to country specific practice. Small error of the calculated data is a main reason to use this country specific method for estimation an annual number of applied urea for these years. For 2012-2017 an interpolation used to make a linear step from FAO to SSSU data. SSSU and FAO reported data for 2018-2019, but these sources have a large data difference. However, FAO reported that these data is "Official data from questionnaires and/or national sources and/or COMTRADE (reporters)" that is why it was a conservative solution to use SSSU data. This solution is in line with "AD sources range". (2) Urea AD include urea that applied as fertilizer on Cropland (for agricultural crops: cereal crops, leguminous crops, industrial crops, roots and tubers, vegetables, food melons, fodder crops and other) and Grassland (hayfields and cultivated pastures).

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LULUCF	L.1	4. General (LULUCF)	For the model used to calculate the net changes in SOM in mineral soils, verify the model's outputs with measurements annually conducted in the country.	As recommended by the ERT possible steps of verification (application of Tier 1 approach) were taken and described in chapter 6.3.4. Ukraine recognizes the need for further verification of the model, by recognizing the need for scientific research into annex 8.2.
	L.2	4. General (LULUCF)	Enhance data collection on the other land uses under which organic soils are reported and on their status, either drained or rewetted or, for wetlands only, natural conditions, and supplement the current data gaps with available ancillary data and expert judgment to ensure that no systematic errors affect the estimates of GHG emissions in the time series of each land-use category.	Ukraine has limited information on organic soils management. Currently reported in the Forest land, Cropland and Grassland organic soils assumed to be all drained (thus N_2O emissions estimated as well). Nevertheless, more accurate data is possible to obtain by overlapping soil type map and land use map when these will be ready.
	L.3	General (LULUCF)	Enhance the information reported in the NIR to improve transparency and include, for each estimated category, the verification of outputs (i.e. GHG estimates), if any, noting that the verification of outputs is mandatory for tier 3 estimates.	See L.1.
	L.5	General (LULUCF)	(1) Improve the documentation of uncertainty estimates reported in NIR table 6.10, particularly when expert judgment is involved; and (2) describe in the NIR the methodology used to calculate total uncertainty, in accordance with good practice to document any expert judgment (2006 IPCC Guidelines, vol. 1, annex 2A.1).	Uncertainties of GHG emissions and removals in the category Forest Land is revised. Revised values are reported in the chapter 6.2.3.
	L.6	Land representation	Collect sufficient data on the land area and changes in the land area, verify the conversions between land-use categories and demonstrate how the accuracy of land representation has improved, clearly documenting the AD used for the sector in the NIR.	Ukraine made efforts to use freely available data for delivering more accurate land representation (described in NIR 2019 chapter 6.1.1). Nevertheless, the results obtained had poor quality, thus was not considered to be the main source for land use matrix recalculation. Ukraine continues to seek for funding to perform in-depth work for land representation improvements.
	L.7	Land representation	Report annual land-conversion areas in CRF table 4.1 and report cumulated 20-year conversion areas in CRF tables 4.A–4.F, which implies the calculation of annual land use and land-use change matrices for the years 1971–1989.	Areas in the CRF table 4.1 was reported on the annual basis. However due to ongoing work with regard to land representation (please see comment on L.6), land use matrices for years 1971-1989 were not developed, but will be delivered after work on land representation based on spatial analysis will be finished.
	L.8	Land representation	Ensure that in any year X of the GHG inventory time series: (1) the area (A_X) of any land-remaining category A is the area of A in the previous year (A_{X-1}) minus the area of A converted in the year X to all other land-use categories	The areas of CRF Table 4.1 was checked. Revised values were reported in the Table 4.1.

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			(A to OLU_X) plus the area converted to A from all other land-use categories 20 years before (OLU to A_{X-20}) (i.e. $A_X = A_{X-1}$ –A to OLU_X +OLU to A_{X-20}); and (2) the area of any land-converted category B to A (B to A_X) is the cumulated area converted to category A from B (B to A) in the 20-year time period from year X to year X–19 (i.e. B to $A_X = \sum_{x-19}^{x} B\ to\ A$).	
	L.11	4.A Forest land	Revise the calculations of GHG emissions and removals from forest land in mineral soils following the methods presented in the 2006 IPCC Guidelines and implement sector-specific QC procedures to ensure the accuracy of the estimates reported across the time series.	The work to define land use categories using GIS is under progress. That would allow to assign proper soil types to land use conversions, and thus select proper SOC_{ref}. For the time being Ukraine applies Tier 1 method, until more accurate data will be available.
	L.12	4.A Forest land	a) recalculate nationwide CSC factors for biomass increments and for DOM net changes, stratified by forest type, ecological region and age class by compiling available information in the country and where feasible by collecting novel data through a national forest inventory system. b) while new CSC factors are being calculated, and noting that Ukraine referenced the use of Buksha et al.'s (2007) report in its 2017 annual submission, the ERT recommends that Ukraine use data contained in table 3.9 (p.126) of Buksha et al.'s (2007) report for biomass increments as stratified by age class and main forest species, together with an age-class distribution for the entire time series 1990–2016 and revise the DOM CSC factors and method to ensure time-series consistency.	The work to deliver consistent time series estimations for the living biomass pool was done. Particularly for the years 1990-2004 estimations of C-gains were revised (see chapter 6.2.2) Tier 1 method and default EFs are applied for CSC in DOM pool until country specific EFs will be available (please see chapter 6 and annex 3.3). Ukraine is unable to apply Tier 2 due to lack of proper country-specific data. The scientific research for estimation of country-specific DOM EFs is recognized in annex 8.2.
	L.16	4.A Forest Land	Improve the explanation in the NIR regarding how the correction factors for estimating carbon loss from disturbances were derived and what the implications may be of using a constant value of the factor.	Discussion regarding use of constant value of correction factor is included into the Annex 3.3.1.
	L.18	4.A.1 Forest land remaining forest land	Include clear definitions of managed and unmanaged forest land and of how unmanaged forest land is detected in the land representation and, if necessary, revise the distribution of forest land between managed and unmanaged.	The definitions were included into chapter 6. Areas of Forest land were reallocated correspondingly. National regulation and methodology is defined how to determinate unmanaged forests (in the national definitions, explained in the chapter 6.2.1).
	L.19	4.A.1 Forest land remaining forest land	Correct the value for the area of forest land remaining forest land in 2015 reported in CRF table 4.A from 10,370.69 to 10,373.36 kha.	The area reported in different tables was checked. The error identified in the table A3.3.1 of NIR and corrected.
	L.20	4.A.1 Forest land remaining forest land	Ensure the time-series consistency of the estimates of gains in living biomass on forest land remaining forest land, including in relation to data on forest age classes and the assumptions for stand age.	The approach to deliver data for the estimation of C-gains by living biomass was revised. More information is reported in the chapter 6.2.2.
	L.21	4.B Cropland	Enhance data collection on the use under which organic soils are reported and supplement the current data gaps with available ancillary data and expert	Please see response to L.2.

Sector	ID#	Category	Recommendation	Comment
			judgment, where needed, to ensure that no systematic errors affect the estimates of GHG emissions in the time series.	
	L.22	4.B Cropland	Include the information on the land-use categories under cropland (arable land, fallow land and gardens) provided to the ERT during the review, namely that (1) the Party does not have information on the spatial distribution of lands because this information depends on the completion of the work on land representation; and (2) for fallow land, it does not have a specific methodology for estimating the effect on carbon stocks and changes of abandoning previously actively used cropland; however because on such lands natural processes of restoration of carbon stocks are occurring, it considers its assumption does not overestimate carbon removals.	The explanation regarding fallow lands is included into chapter 6.3.2.
	L.24	4.C.1 Grassland remaining grassland	Use subdivisions of managed grassland to report those areas of grassland that are not subject to changes in management activities or for which management activities do not result in net emissions or net removals of GHGs.	Ukraine considered all grasslands to be managed in NIR 2019. Ukraine does not see the need to exclude any area of grasslands from the calculations of CSC at the moment since there are no national regulations of formal definition of such areas (unlike forests).
	L.28	4.D.1 Wetlands remaining wetlands	Enhance the data collection on the drainage status of peat production sites once abandoned; supplement the current data gaps with available ancillary data and expert judgment where needed; and estimate GHG emissions in sites for peat production which, although abandoned, are still under drainage to ensure that no errors affect the GHG emission trend.	Initial search of information demonstrated that there is limited information on status of lands previously drained including peat extraction sites. The work to collect information on status of these lands are continuing, It is foreseen that the work on use of GIS could deliver more accurate land use transition matrices will contribute to address this recommendation as well. Ukraine also seeks experts with knowledge of peat extraction sites management.
	L.29	4.D.2 Land converted to wetlands	Report all land converted to wetlands under the organic soils subdivision and discount such areas from the original land-use category area of drained organic soils.	In order to keep consistent reporting of soils it is essentially that previous land use before conversions to Wetlands would have organic soils as well. But since there is an information on organic soils of Forest land, Cropland and Grassland and the area of organic soils in these categories is rather stable it is possible that the conversions were on mineral soils. However, this recommendation is highly connected to accurate land representation. As soon as spatial data will be available to deliver land use matrices and soils of Ukraine, this issue can be addressed.
	L.19	4.F Other land	Revise the classification of category 66 ("dry open lands with special vegetation cover"), noting that category 66 appears to more closely match the definition of the IPCC category grassland than other land.	New statistical form 16-zem has other categories, thus category 66 is not applicable anymore. The revision of historical data is not

Sector	ID#	Category	Recommendation	Comment
				reasonable at this moment since the work on use of GIS to deliver more accurate land use transition matrices is expected to address this recommendation anyways.
	L.31	4.F.2.1 Forest land converted to other land uses	Subdivide and report separately deforested areas between those that did contain trees and those that did not contain trees before deforestation; report in the NIR a table where, for each carbon pool, the standing carbon stocks before deforestation and after deforestation are reported for those lands that did contain trees before deforestation.	The recommendation is closely related to L.6. Delivering of land use-change matrix based on spatial data is expected to address this recommendation as well.
	L.32	HWP	Explain in the NIR the methodology used for estimating emissions from HWP, including the splicing technique, the use of GDP data and the World Bank as the source of the GDP data, and the use of 2010 prices.	More information is added into chapter 6.8.2.
	L.35	4.A Forest Land	Transparently describe in the next NIR the additional causes for the large change in the estimated emissions for 2003–2006 relative to the other years in the time series.	Recalculations are explained in the chapter 6.2.5. Significant changes in emissions and removals may occur due to combination of factors at any of years (data clarification, emission and other factors, errors elimination).
	L.38	Land representation	Reclassify the areas of other land to a land use that is more representative of the land category, where land-use conversion from other land to forest land, cropland and grassland has taken place.	See L.6.
	L.40	4.A Forest Land	Follow equation 2.11 of the 2006 IPCC Guidelines (vol. 4, chap. 2) and report all losses for biomass in CRF table 4.A, regardless of whether or not the losses are associated with timber for HWP production.	C-losses from living biomass were revised to address this recommendation. Particularly C-losses includes emissions from all wood harvested in Ukraine no matter whether it was used in the HWP or not. The results of the recalculations are reported in chapter 6.2.5.
	L.41	4.B Cropland	(a) Describe in more detail in the NIR the changes to crop structure, harvest volumes of specific crop types and volume of fertilizer application to transparently justify the large inter-annual changes in emissions, and provide information on the drivers behind these changes in comments beneath a figure presenting the time series (e.g. revised figure 6.2). NIR figure 6.2 (p.203) does not cover the years with the greatest inter-annual variability. The changes would be more transparently explained if the data provided in figure 6.2 were expanded to show the years where these large inter-annual variations in emissions occur; (b) Report in the NIR the years where SSSU alters its methodology for data collection and describe the methods that the inventory team applies to ensure time-series consistency when these data collection methods are changed.	a) Figures 6.2 and 6.3 and table 6.8 include the most recent years. The drivers of CSC changes are described in the chapter 6.3.2. The drivers of changes in crop types, amount of fertilizers application and crop harvest has a management nature, since the State Statistic Service of Ukraine collects data as it is from the respondents. b) it is not possible to separate and report every year of any changes in the methodology of data collection by the State Statistic Service of Ukraine or any changes to the reporting forms, spreadsheets, scope or allocation since neither the State Statistic Service of Ukraine nor the

Sector	ID#	Category	Recommendation	Comment
				GHG inventory team do not keep track of those since 1990.
Waste	W.1	General	Improve the description in the NIR of the solid waste management practices in the country, including landfilling of MSW (with and without CH4 recovery), composting, incineration, recycling and management of hazardous waste.	The information on the management of landfilling of MSW (and industrial waste), recycling, composting, incineration and hazardous waste is described in section 7.2.2.2 of the NIR. The information on the methane utilization at MSW dumps with and without energy recovery described in section 7.2.2.4 of the NIR.
	W.2	General	Revise the schematic representation of waste treatment (NIR figure 7.3) by including all categories (in all relevant sectors), the sources of each type of waste, ways of treatment and final destination, particularly of sludge from wastewater treatment.	The schematic representation of waste treatment was revised (see figure 7.3 in the NIR).
	W.3	5.A Solid waste disposal	Continue to further investigate MSW, taking into consideration the fact that the sampling should be conducted in several typical cities in each season and that the methods, frequency of sampling and implications for the time series should be documented with a view to developing a country-specific EF for the category.	Ukraine uses the default value of degradable organic carbon for food waste and for other types of waste from the 2006 IPCC Guidelines. Systematic research on the morphological composition of MSW in Ukraine have not been conducted. However, expert assessments were done under some recent projects funded by International Financial Institutions (IFIs) and concluded that the MSW generation structure in Ukraine closer to Eastern European countries (Poland, Czech Republic, Slovakia, Baltic States, etc.). The organic fraction in Ukraine is greater than that in other European countries, while the shares of glass and plastic are relatively low (see section 7.2.2.3).
	W.10	5.D Wastewater treatment and discharge – CH_4	The ERT recommends that the Party improve the transparency of the NIR by reporting a complete sludge balance, including the total amount produced (from domestic and industrial wastewater) and the amount sent to each of the different treatments (landfill, composting, incineration and agriculture), specifying the categories where the related emissions are accounted for.	An explanation on sewage sludge management in Ukraine is provided in the section 7.5.2.2.3. The sludge balance is presented in table 7.27 of the NIR.
	W.11	5.D Wastewater treatment and discharge – N_2O	The ERT recommends that the Party report consistent data on population and protein consumption under additional information in CRF table 5.D and NIR table 7.26.	The data on the population and protein consumption provided under additional information in CRF table 5.D and NIR table 7.26 were consistent.

A8.2 Improvement Plan for the NIR

Taking into account the recommendations of the ERT contained in the ARR 2021, as well as the national planning process to improve the inventory system, below is a list of the areas where work should start as soon as possible.

IPCC sector	IPCC category	Description of improvements	NIR submission year when the improvement implementation is planned	Current status of implementation/financing/exploration of work on improvement implementation	Notes
Energy	1.A Fuel combustion activities	Development of country-specific CO_2 EF for residual fuel oil	2024-2026	Funding is envisaged from different sources including international technical assistance	
	1.B.2 Oil and Natural Gas	Development of the method to account for greenhouse gas emissions by sources and losses of natural gas for end users in Ukraine to carry out the national greenhouse gas inventory	2024-2026	Funding is envisaged from different sources including international technical assistance	
	1.B.2.b Natural gas	Development of country-specific CH_4 and CO_2 EFs	2024-2026	Funding is envisaged from different sources including international technical assistance	
	1.B.2.c Venting and Flaring	Development of country-specific CH_4 and CO_2 EFs	2024-2026	Funding is envisaged from different sources including international technical assistance	
Industrial Processes and Product Use	2.C.1 Iron and Steel production 2.C.2 Ferroalloys Production	Development of methodological guidelines on determination of carbon dioxide emissions from limestone, dolomite, and other reducing agents use in pig iron, steel and ferroalloys production, with adjustment of the estimations according to 2006 IPCC Guidelines	2024-2026	Taken for consideration to amend the activity plan of the MEPR. It is expected to attract financing	
	2.F Use of Ozone-Depleting Substances 2.G.1 Electric Equipment	Analysis and development of methodological guidelines on determination of the emissions from manufacturing, stocks and disposal of equipment containing HFCs, PFCs, and SF_6.	2024-2026	Taken for consideration to amend the activity plan of the MEPR. It is expected to attract financing	
Agriculture	3.B Manure Management	Scientific researches on environmental impact assessment of the cattle and swine manure distribution, and the various systems for its managing	2024-2026	The offer for including to the MEPR activity plan. State funding	
LULUCF	4.A Forest land	Development and clarification of national factors for carbon stock changes in living biomass, dead organic matter and soil pools in the Forest Land category	2024-2026	Funding is envisaged from different sources including international technical assistance	
	4.B Cropland 4.C Grassland	Improvement of parameters and factors used in the model of balance estimations of nitrogen flows in soils used in the GHG inventory in the categories Cropland and Grassland	2024-2026	Funding is envisaged from different sources including international technical assistance	

IPCC sector	IPCC category	Description of improvements	NIR submission year when the improvement implementation is planned	Current status of implementation/financing/exploration of work on improvement implementation	Notes
	4.B Cropland 4.C Grassland	Verification of calculation results from Tier 3 model application in soil organic matter pool of Cropland and Grassland categories by design and performance of measurements	2024-2026	Funding is envisaged from different sources including international technical assistance	
	4.A Forest land 4.B Cropland 4.C Grassland 4.D Wetlands 4.E Settlements 4.F Other Land	Estimation of carbon stock changes in soil pool during conversions between land-use categories	2024-2026	Funding is envisaged from different sources including international technical assistance	
Waste	5.A Solid Waste Disposal	Investigation of the MSW composition in Ukraine	2024-2026	Funding is envisaged from different sources including international technical assistance	
	5.A Solid Waste Disposal	Monitoring and type definition (classification) of solid waste disposal sites (SWDS) in Ukraine	2024-2026	Funding is envisaged from different sources including international technical assistance	
	5.D Wastewater Treatment and Discharge	Approach improvement for the estimation of emissions (CH_4, N_2O) from domestic and industrial wastewater treatment and sludge management	2024-2026	Funding is envisaged from different sources including international technical assistance	

In the field of organization of work on preparation of the GHG inventory, control and assurance of its quality in accordance with 2006 IPCC Guidelines and the International ISO 9001 Standard for quality management systems, the Ministry of Ecology and Natural Resources of Ukraine in the framework of the Clima East program: Support to Climate Change Mitigation and Adaptation in ENP countries and Russia applications were prepared and submitted for provision of expert assistance at the initial stages of improvement of the inventory within the topics "Development and clarification of national factors of GHG emissions and removals in the Forest Land category" and "Estimation of greenhouse gas emissions from use of vehicles in Ukraine".

In the framework of realization of Agreement between Ministry of Energy and Coal Industry of Ukraine and Ministry of foreign affairs of Denmark on development and cooperation for the Ukraine-Denmark Energy Center according to Output 2 indicator "Methodology for GHG registry and UNFCCC" the project "Calculations of Greenhouse Gas Emissions from Coal Combustion in Thermal Power Plants of Ukraine for 1990-2015" was carried out that resulted in scientifically based recalculations of CO_2 emissions from coal combustion at the TPPs of Ukraine.

Funding for research works indicated in the table above is envisaged from different sources including international technical assistance.

Moreover, the Ministry of Ecology and Natural Resources is making efforts to attract financing for development of twenty-five studies in the sectors of Energy, LULUCF, IPPU, Agriculture and Waste.