Ministry of Ecology and
Natural Resources of Ukraine

UKRAINE'S
GREENHOUSE GAS INVENTORY
1990-2016

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

Kyiv - 2018

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 2016 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"). Moreover, being a party to the Kyoto Protocol, in this report Ukraine submits additional information set out in paragraph 1, Article 7 of the Kyoto Protocol (hereinafter - KP) in accordance with Decision 15/CMP.1.

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

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The National Inventory Report was prepared by the MENR 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 16 of this report.

EXECUTIVE SUMMARY

ES.1 Background information on greenhouse gas inventories, climate change and supplementary information required under Article 7.1 of the Kyoto Protocol

The Verkhovna Rada (Parliament) of Ukraine 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 1990-2016 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 MENR.

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).

This report consists of two parts.

The first part encloses chapters from 1 to 10 which contain the information related to annual GHG inventory.

Chapter 1 provides background information on climate change and general information on GHG inventories. This chapter offers a description of the national GHG inventory system under Article 5.1 of the Kyoto Protocol, which is designed to ensure compliance with the requirements for reporting on GHG emissions and removals. Besides, this 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 within the primary improvement of the national inventory system and QA/QC system, as well as aiming to consider and implement recommendations and encouragements, gained from ERT during the process of annual inventory review, according to Decision 22/CMP.1.

The second part of this report encloses chapters from 11 to 15 which are related to reporting of Ukraine in accordance with Article 7 of the Kyoto Protocol.

Chapter 11 presents all information on LULUCF activities under Articles 3.3 and 3.4 of Kyoto Protocol, as defined by Decisions 11/CMP.1, 15/CMP.1, 16/CMP.1, and 6/CMP.3. In particular, this chapter provides a definition of the term "Forest", describes the activities defined by Ukraine for reporting under Articles 3.3 and 3.4 of the Kyoto Protocol, as well as describes methods, activity data, and emission factors used to estimate emissions and removals.

Chapter 12 is focused on describing accounting of Kyoto units in Ukraine, as required under Decision 13/CMP.1.

The process of preparation of national registry functioning report and its review by independent experts (Standard Independent Assessment Report - SIAR) should be performed with accordance with Decisions 16/CP.10 (paragraphs 5(a), 6(c) and 6(k)), and with accordance of requirements, formats and methodological recommendations of administrator of International Transaction Log (ITL), which are approved by Registry System Administrators Forum of the Kyoto Protocol.

Chapters 12 and 14 in terms of Registry operation shall be maximum updated, if possible.

Chapter 13 describes the changes in the national inventory system of Ukraine, in accordance with Decision 15/CMP.1.

The key objective of submitting the information in Chapters 13 and 14 is to demonstrate that the changes implemented have not led to any unacceptable deviations from the reporting requirements under the Kyoto Protocol.

Chapter 15 describes actions of Ukraine aimed at minimizing of adverse impacts, in accordance with Article 3.14 of the Kyoto Protocol.

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; additional information required under Article 7.1 of the Kyoto Protocol.

ES.2 Summary on national trends of emissions and removals, including KP-LULUCF activities

ES.2.1 GHG inventory

As a result of the temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol by the Russian Federation and its further military aggression in certain areas of the Donetsk and Luhansk regions, 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 Inventory.

The temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol as well as the Russian Federation military aggression in certain areas of the Donetsk and Luhansk regions 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

[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

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 military 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 territories, which are temporary out of control by Ukrainian authorities, expert estimation was performed [1], 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 2014-2016 for the rest of the territory of Ukraine.

GHG emissions in Ukraine in 2016 amounted to 338.64 Mt CO_2-eq. excluding the sector Land Use, Land-Use Change and Forestry (hereinafter - LULUCF), what is 64.3 % lower than in the base 1990 level, but 6.2 % higher than in 2015. With the LULUCF sector, emissions in 2016 amounted to 320.64 Mt CO_2-eq. and decreased in comparison with base year by 63.9 %, while in comparison with 2015 increased by 8.0 %.

The largest share of GHG emissions in the base year is carbon dioxide - 72.8 % with LULUCF. Methane emissions in 1990 were 21.3 %, and those of nitrous oxide - 5.8 %. In 2016, the proportion somewhat changed - 67.7 %, 21.2 %, and 10.8 % for carbon dioxide, methane, and nitrous oxide, respectively.

CO_2 emissions take place in all sectors, as well as net removals of CO_2 in the LULUCF sector. CO_2 emissions in 1990 amounted to 647.63 Mt and decreased as of 2016 by 66.5 %, to the level of 217.03 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.

CO2 emission trend in 2008-2016 was determined by the influence of the global financial and economic crisis in 2008 - 2009 and a temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol as well as the Russian Federation military invasion in certain areas of the Donetsk and Luhansk regions in 2014, which largely determined commodity production in the major export-oriented industries (metallurgy, chemical, mechanical engineering, etc.), which in turn affect supply sectors - electric power generation, mining (ore and coal mining)[2].

Totals of 2015-2016 is presenting the result of intensification of growth in economy in the country. The annual indices of industry in accordance with the State Statistical Service of Ukraine was decreasing since 2013 till 2015. In 2016 industrial production index was 102.8% comparing with 2015.

In 2016 emissions slightly increased in all sectors. This is seen as recovery of economy of Ukraine.

Moreover, during the entire time series since 1990 to 2016 GHG removals were decreasing, what was connected mainly with national practices of cropland and grassland management, as well as forestry.

Emissions of CH_4 are the second largest after CO_2 if considering their share in total GHG emissions. In 2016 CH_4 emissions in Ukraine amounted to 67.99 Mt CO_2-eq., what is 64.1% lower compared to 1990, but 7.4 % higher than in 2015 (Table ES.2.1). In 2016, the percentage distribution

[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

by sectors was: 65.0 % - Energy, 17.5 % - Agriculture, 16.5 % - Waste and the rest was emitted in the remaining sectors, what is somewhat different from 1990 (Energy sector - 67.5 %, Agriculture - 26.3 %, and Waste - 5.4 %). 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 was accompanied by reduction in agricultural production, which led to reduced methane emissions in the Agriculture sector in 2015 to 475.95 kt, what is more than four times lower than in 1990.

Nitrous oxide emissions in Ukraine with the LULUCF sector in 2016 amounted to 34.71 Mt CO_2-eq., which in comparison with 1990 (51.97 Mt CO_2-eq.) is 33.2 % lower (Table ES.2.1). Compared with 2015, emissions of nitrous oxide increased by 10.1 %. The dominant source of nitrous oxide emissions in Ukraine, as in the previous submissions, is the Agriculture sector - 86.3 % of total nitrous oxide emissions in 2016. Emission sources in this sector are agricultural soils and manure management. Moreover N_2O emissions take place in the sector Industrial Processes and Product Use (IPPU) (5.8 %), Energy (4.3 %), Waste (3.2 %), as well as LULUCF (0.4 %).

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

ES.2.2 KP-LULUCF activities

In the current NIR Ukraine provides data on the GHG emissions and removals, that take place in the LULUCF sector in regarding afforestation and reforestation activities (paragraph 3, Article 3 KP) and forest management (paragraph 4, Article 3 KP) for the first years of the second KP reporting period (Table ES.2.2).

Table ES.2.2. GHG emissions (+) / removals (-) from activities under paragraphs 3 and 4, Article 3 KP, kt CO_2-eq.

The volume of emissions/sinks from the activities	**2013**	**2014**	**2015**	**2016**
Afforestation and reforestation activities	-929.73	-972.76	-1079.44	-1251.29
Deforestation	12.02	8.54	8.41	9.10
Activities under Article 3.3	-917.71	-964.22	-1071.03	1242.19
Activities under Article 3.4 Land category B.1 Forest management	-69087.86	-69614.42	-68962.59	-67560.98

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

Gas	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	Current year compared to base year, %
CO_2 (excluding LULUCF)	705.8	389.9	279.5	313.5	293.5	307.1	303.7	296.1	256.6	223.6	235.2	-66.7
CH_4	189.4	140.6	118.6	104.8	86.7	88.0	82.7	77.5	71.0	63.3	68.0	-64.1
N_2O	52.0	31.0	22.6	25.0	26.5	32.0	30.8	34.0	33.8	31.5	34.7	-33.2
HFCs*	NO	NO	15.7	285.2	744.1	820.4	841.3	881.8	848.4	775.6	889.0	-
PFCs*,*	235.8	178.1	115.7	142.3	26.7	NO	NO	NO	NO	NO	NO	-
SF_6*	0.0	0.1	0.4	4.5	9.7	8.4	11.0	12.5	16.7	19.4	24.1	315828.4
NF_3*	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
Net CO_2 from LULUCF	-58.2	-53.1	-45.7	-36.2	-37.3	-27.2	-33.6	-21.1	-20.3	-22.3	-18.1	-68.8
CO_2 (including LULUCF)	647.6	336.7	233.9	277.3	256.2	279.9	270.1	275.0	236.3	201.3	217.0	-66.5
Total (excluding LULUCF)	947.3	561.3	420.5	443.5	407.3	427.8	417.8	408.3	362.0	319.0	338.6	-64.3
Total (including LULUCF)	889.3	508.5	375.1	407.6	370.2	400.8	384.4	387.4	342.0	296.9	320.6	-63.9
Total (excluding LULUCF), including indirect CO_2	947.3	561.3	420.5	443.5	407.3	427.8	417.8	408.3	362.0	319.0	338.6	-64.3
Total (including LULUCF), including indirect CO_2	889.3	508.5	375.1	407.6	370.2	400.8	384.4	387.4	342.0	296.9	320.6	-63.9

*emissions quoted in kt CO_2-eq.

** there is no PFC emissions, as cooling agents containing the gas were not imported in 2011-2016

ES.3 Overview of source and sink category emission estimates and trends, including KP-LULUCF activities

ES.3.1 GHG inventory

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 2016, the share of this sector accounted for around 66 % without the LULUCF sector. About 80% 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 20 % - 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 17.5 % in 1990 to 29.2 % 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 20.4 % in 2016, which is due to activities in the field of energy efficiency and energy source replacement implemented in the country.

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

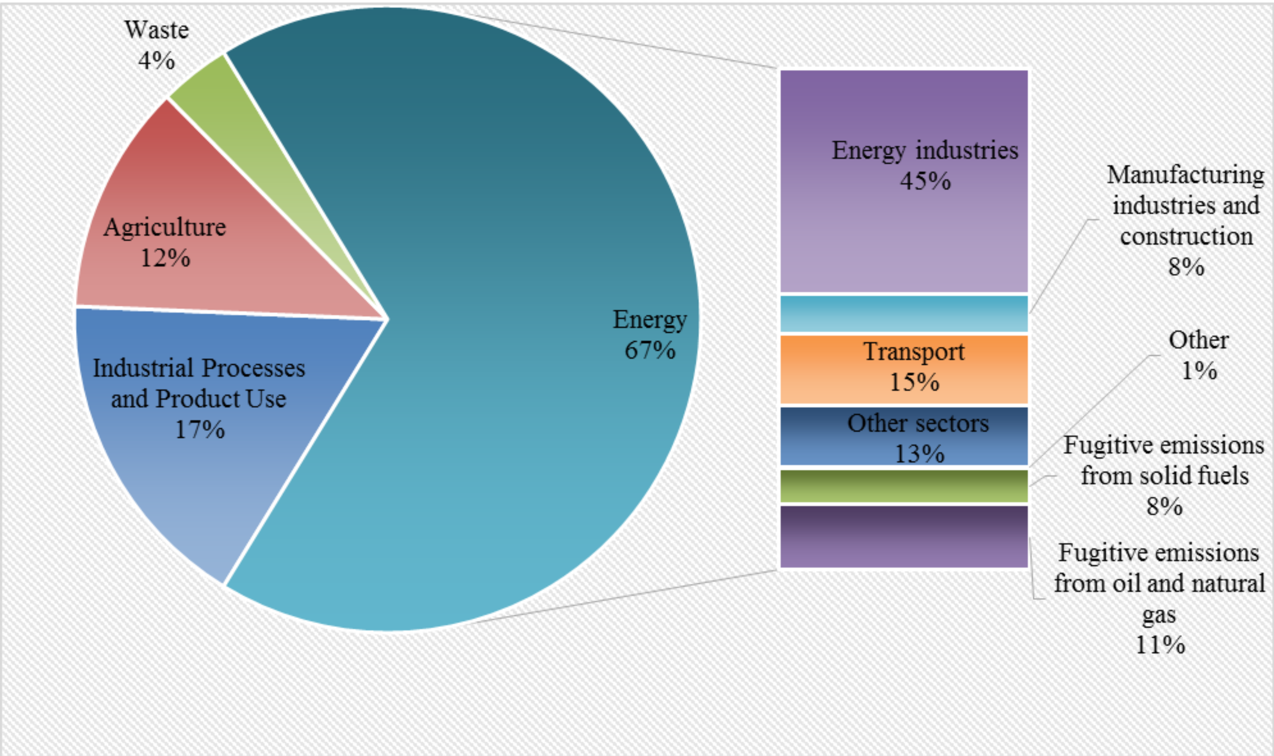

Fig. ES.3.1. The GHG emission structure in 2016

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 2016, emissions in the IPPU sector decreased by 50.8 % 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.

The share of the Agriculture sector in total GHG emissions without LULUCF was 12.5 % in 2016. The major sources of emissions in the Agricultural sector are enteric fermentation and agricultural soils, 25.3 % and 68.0 % of the total emissions in the sector in 2016, respectively. Emissions in this sector decreased by 53.9 % compared to the base year, but increased by 6.6 % as compared to previous year.

The LULUCF sector includes both emissions and reductions of carbon dioxide. In this sector, there are emissions of CO_2, CH_4, and N_2O. The resulting values of the inventory in the LULUCF sector are net removals. Net removals of CO_2 in this sector reaches up to 11.7 % of the total annual GHG emissions in 1999 calculated without LULUCF (Fig. ES.3.2). The value of net CO_2 removals in the sector in 2016 decreased by 69.0 % compared to the base 1990 year. The main reason for such decline 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 47.3 Mt CO_2-eq. of emissions in 2016. Particularly, significant influence has the areas of harvested crops from those lands, as well as fertilizers applied.

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 2016.

The contribution of the Waste sector in 2016 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 increased by 3.7 % in 2016.

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

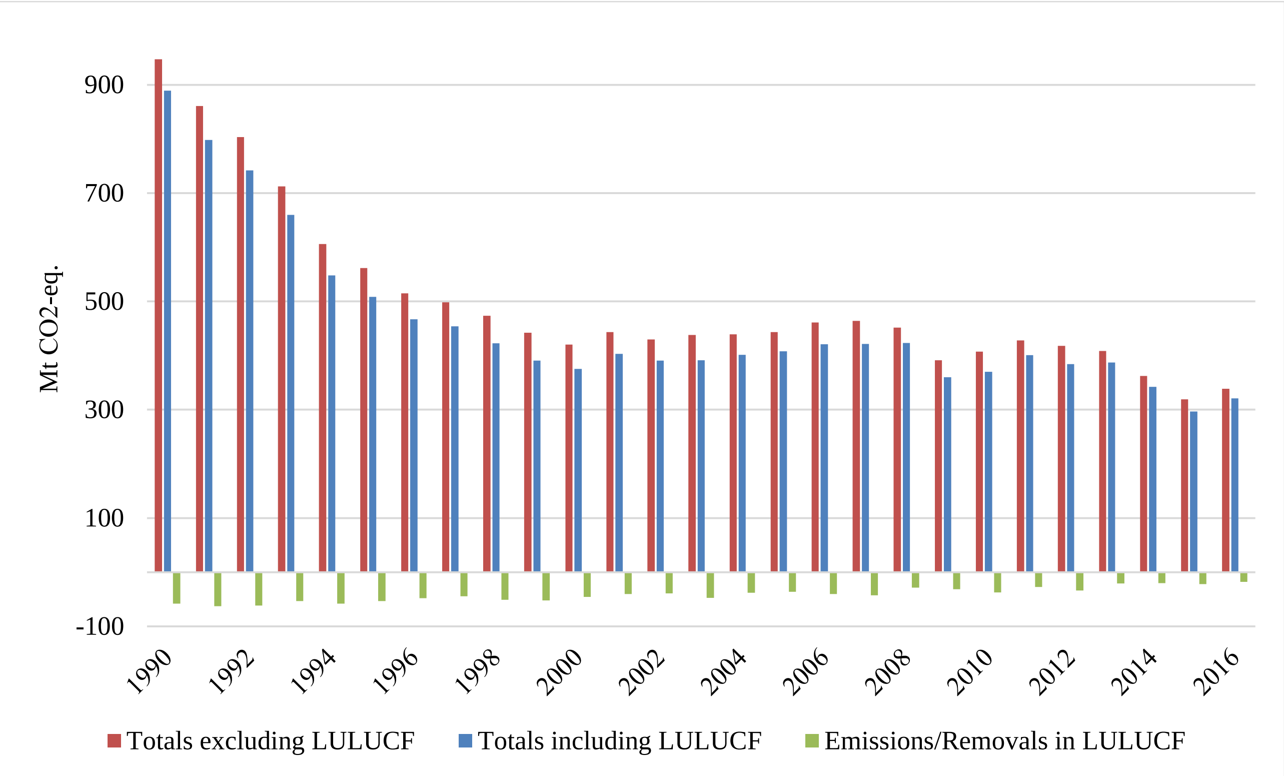

Fig. ES.3.2. Total GHG emissions (+) and removals (-) with and without the LULUCF sector for the period of 1990-2016, Mt CO_2-eq.

Table ES.3.1 reflects trends in aggregate GHG emissions by sector for the period of 1990-2016.

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

Sector	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	Current year compared to base year, %
Energy	725.3	431.4	305.5	315.5	285.8	295.5	290.0	280.9	245.7	210.5	225.8	**-68.9**
Industrial Processes and Product Use	118.0	58.0	67.1	80.6	74.5	80.8	77.3	72.4	61.9	56.5	58.0	**-50.8**
Agriculture	92.0	60.4	36.5	35.3	34.6	38.9	38.0	42.4	42.1	39.8	42.4	**-53.9**
LULUCF (removals)	-58.0	-52.8	-45.4	-35.9	-37.1	-27.0	-33.4	-20.9	-20.1	-22.1	-18.0	**-69.0**
Waste	11.9	11.5	11.4	12.0	12.4	12.5	12.4	12.5	12.4	12.3	12.4	**3.7**
Total (including LULUCF)	889.3	508.5	375.1	407.6	370.2	400.8	384.4	387.4	342.0	296.9	320.6	**-63.9**
Total (excluding LULUCF)	947.3	561.3	420.5	443.5	407.3	427.8	417.8	408.3	362.0	319.0	338.6	**-64.3**
Total (including LULUCF), including indirect CO_2	889.3	508.5	375.1	407.6	370.2	400.8	384.4	387.4	342.0	296.9	320.6	**-63.9**
Total (excluding LULUCF), including indirect CO_2	947.3	561.3	420.5	443.5	407.3	427.8	417.8	408.3	362.0	319.0	338.6	**-64.3**

ES.3.2 KP-LULUCF activities

Implementation of activities under paragraphs 3 and 4, Article 3 KP leads to a change in carbon stocks as a result of:

- increasing in carbon stocks (removals) accumulated in the processes of:
  - afforestation and reforestation;
  - forest management.
- decreasing in carbon stocks (emissions) resulting from:
  - deforestation;
  - harvesting;
  - fires occurring not due to human-induced activity.

The category Afforestation and Reforestation in the context of paragraph 3, Article 3 KP includes volumes of net carbon emissions/removals as a result of activities of afforestation and further forest management on these areas. The report provides data for the second KP reporting period.

The category Deforestation in the context of paragraph 3, Article 3 KP count the territories, which were deforested with aim to use it in other land-use categories. The report provides information for the years 2013-2016. For afforestation activities, an assessment of carbon stock changes for all required pools was conducted separately. In addition, in accordance with requirements of IPCC 2006, nitrogen losses were estimated at land conversion to other land-use types.

In the context of paragraph 4, Article 3 KP, changes in carbon stocks in the pool of living biomass and dead organic matter in forest territories constantly covered with forest vegetation are accounted for. The report presents data for 2013-2016. For forest management activities, carbon stocks reduction in the pool of living biomass as a result of harvesting in managed forests is accounted for (under statistical form 3-lg). Estimation of changes in carbon stocks was held for all required pools separately (an exception is estimation of carbon losses in the below-ground biomass pool, which is accounted for in the above-ground, as well as a proof of absence of emissions from the pool is offered for the pool of mineral forest soils under managed forests).

Separately emissions from fires were reported, occurred in forests without human-induced activities on burning for 3.3 and 3.4 KP activities.

Separate assessment was conducted for carbon stock changes in harvested wood products for afforestation and forest management activities. Wood from deforestation-related harvesting was reported as loss of biomass with the instantaneous oxidation approach.

ES.4 Other Information

This section indicates sulfur dioxide and precursors emissions: nitrogen oxides, carbon monoxide, non-methane volatile organic compounds (NMVOC). Precursors 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 1990-2016.

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

Gas	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	Change, %
NO_x	2 466.1	1 248.5	838.5	896.0	770.0	804.1	770.5	762.6	670.2	564.8	580.8	-76.4
CO	4 357.3	1 729.9	1 169.1	1 264.0	1 128.7	1 116.0	1 118.1	1 116.5	1 018.3	919.0	822.6	-81.1
NMVOC	3 553.0	2 011.4	1 487.9	1 552.6	1 211.6	1 253.7	1 155.3	1 147.4	1 001.0	858.4	868.5	-75.6
SO_2	2 194.7	1 410.5	673.4	806.9	838.8	916.8	958.2	969.5	853.4	754.0	801.2	-63.5

Comparing with 1990. precursors and sulfur dioxide emissions in Ukraine decreased by 65.6-78.9 %. 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	2011	2012	2013	2014	2015	2016	Change. %
Indirect CO_2 (with LULUCF)	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NA.NO	NO.NA	NO.NA	-
Indirect CO_2 (without LULUCF)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-
Indirect N_2O	11.79	5.97	4.01	4.28	3.68	3.85	3.68	3.65	3.20	2.70	2.75	-76.68

CONTENT

1 INTRODUCTION

1.1 Background information on greenhouse gas inventories, climate change and supplementary information required under Article 7.1 of the Kyoto Protocol

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°C/10 years in 1961-2013. Since late 1990s, a stable transition of the annual air temperature anomaly to above 0°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 temporary occupation of the 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.

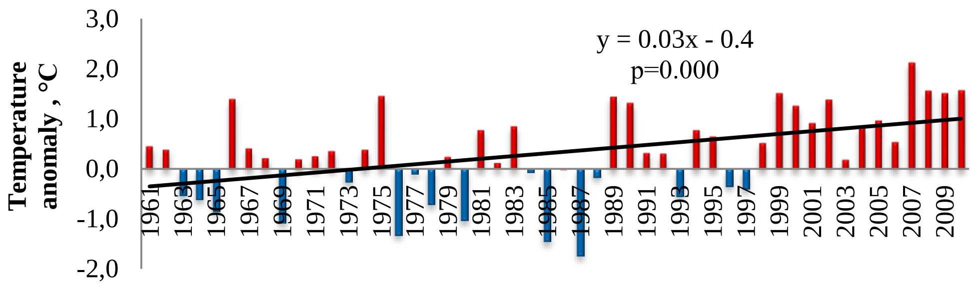

Fig. 1.1. Anomalies of annual air temperature in Ukraine with respect to the 1961–1990 reference period [3]

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°C, respectively, in 1991-2013 (Fig.1.2). Also, the air temperature rise was the highest in January (2.3°C) and July (1.4°C). The average temperature in spring increased by 0.8°C mostly due to temperature anomaly observed in March. There was only a minor change of autumn temperature (0.4°C) [3].

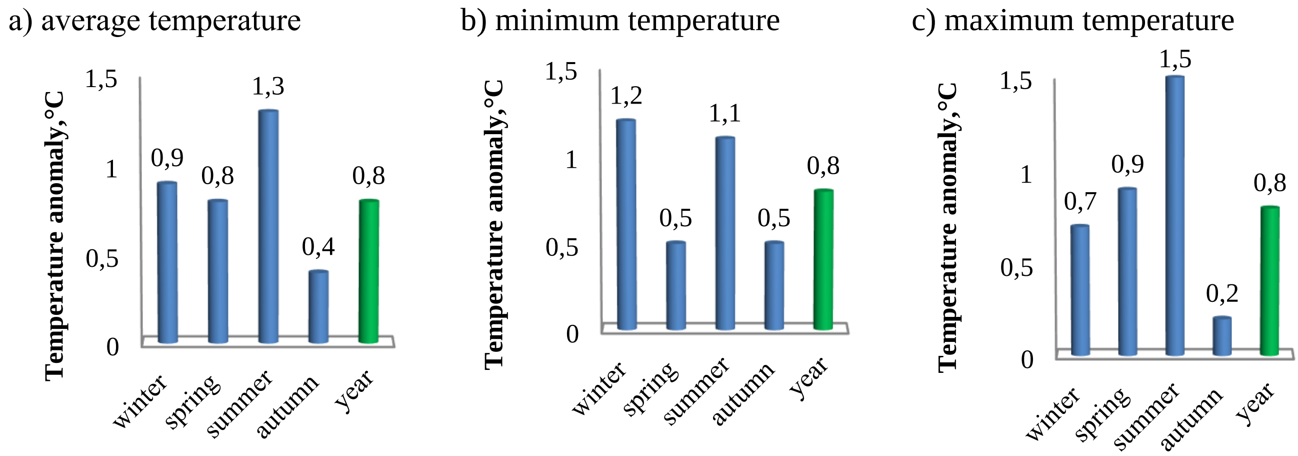

Fig.1.2. Anomalies of average (a), minimum (b) and maximum (c) air temperatures per seasons and year in 1991-2013 with respect to the 1961–1990 reference period [3]

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).

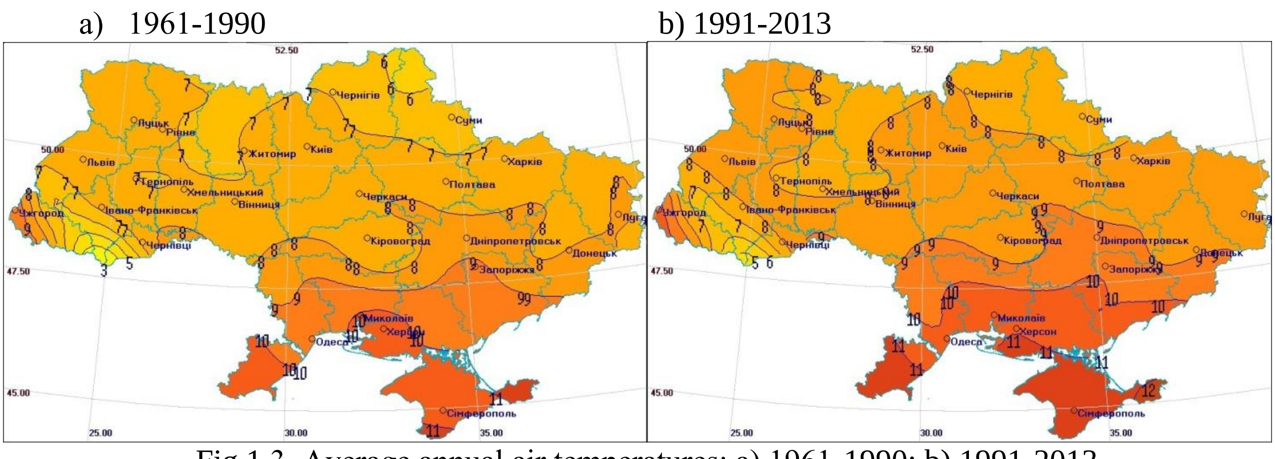

Fig.1.3. Average annual air temperatures: a) 1961-1990; b) 1991-2013

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

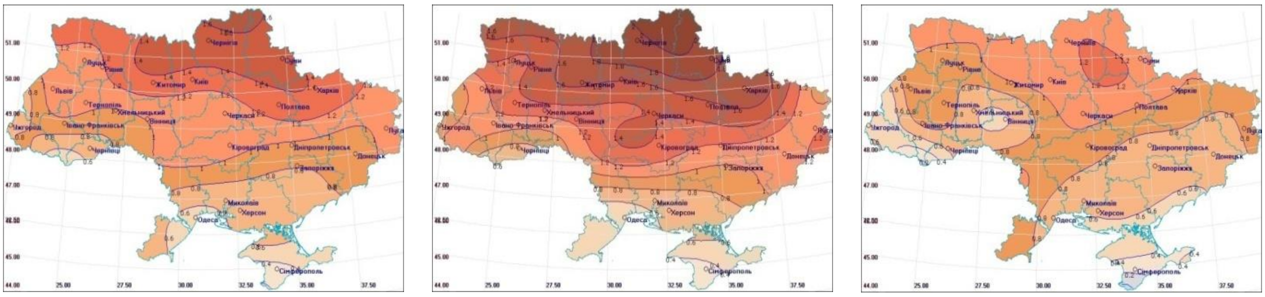

Fig. 1.4. Anomalies (°C) of average, minimum and maximum winter air temperatures in 1991-2013 with respect to the 1961–1990 reference period

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

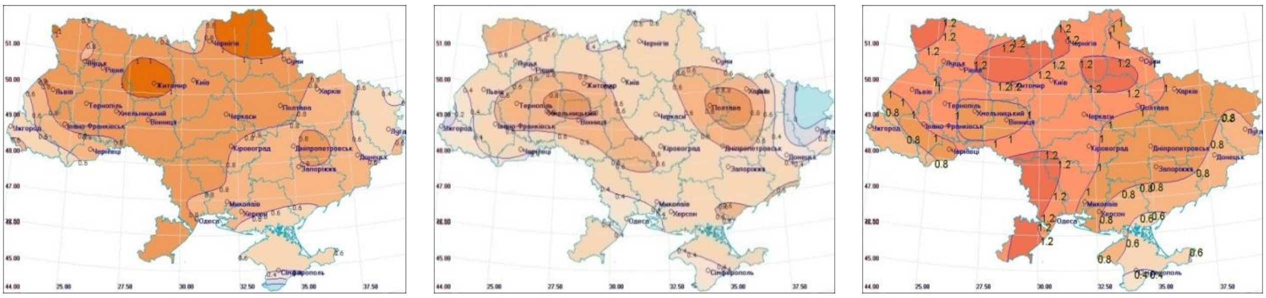

Fig. 1.5. Anomalies (°C) of average, minimum and maximum spring air temperatures in 1991-2013 with respect to the 1961–1990 reference period

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

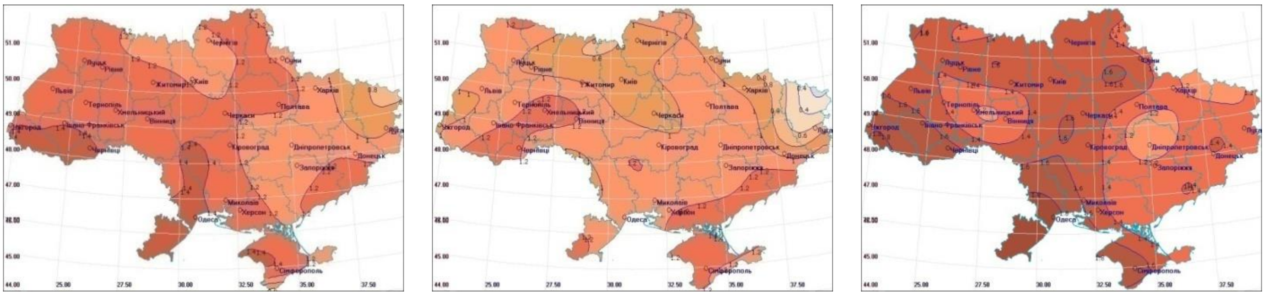

Fig. 1.6. Anomalies (°C) of average, minimum and maximum summer air temperatures in 1991-2013 with respect to the 1961–1990 reference period

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

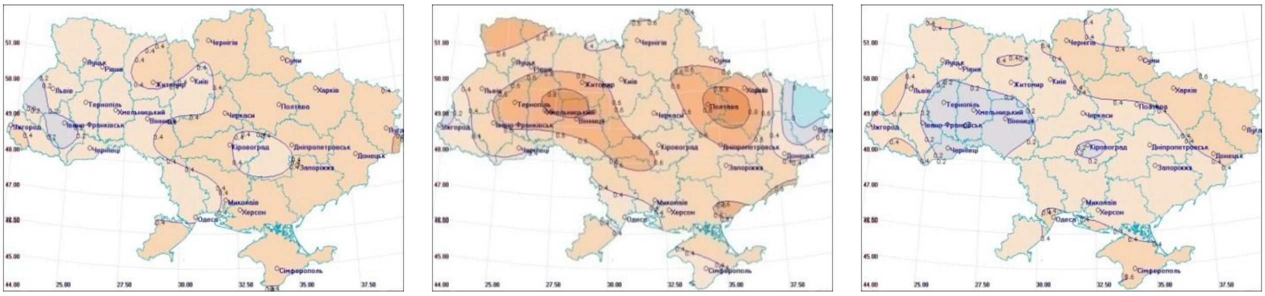

Fig. 1.7. Anomalies (°C) of average, minimum and maximum autumn air temperatures in 1991-2013 with respect to the 1961–1990 reference period

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°C, 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 21st 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].

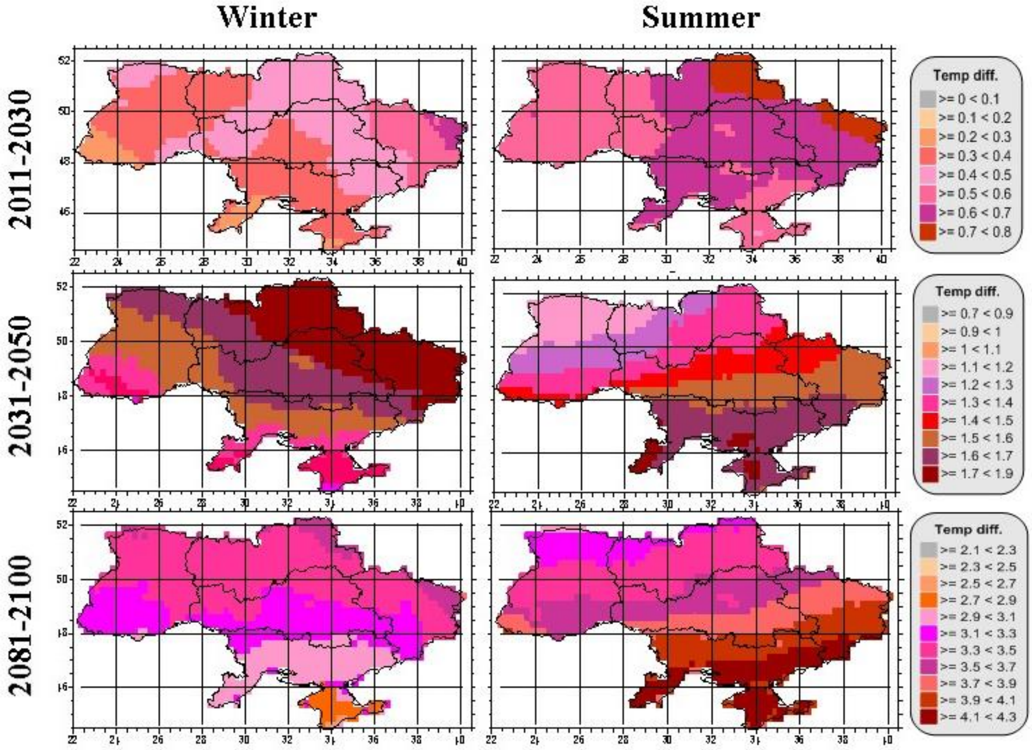

Fig. 1.8. Changes of air temperatures in winter and summer during the three forecast periods (2011-2030, 2031-2050, and 2081-2100) against the present period of 1991-2010 for ensemble with ten RCMs

The main trends of the projected climate conditions in Ukraine in the 21st 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°C have been obtained. At the same time, average monthly summer temperatures above 25°C 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"). This report includes the additional information specified in paragraph 1, Article 7 of the Kyoto Protocol. The preparation was carried out with regard of 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 in accordance with the "2006 IPCC Guidelines on National Greenhouse Gas Inventories" (hereinafter – 2006 IPCC Guidelines) to implement the COP Decision (24/CP.19).

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 (Warsaw, 2013).

1.1.3 Background information on information required under Article 7, paragraph 1 of the Kyoto Protocol

Ukraine as UNFCCC Annex I Party, as well as a Party to the Kyoto Protocol submits supplementary information in accordance with the requirements of Article 7.1 of the Kyoto Protocol, as defined in Decision 15/CMP.1. This supplementary information includes data on:

1) amounts of emissions and removals by forest ecosystem pools as a result of LULUCF activities, under paragraphs 3 and 4, Article 3 of the Kyoto Protocol, as specified in section I.E in the annex to Decision 15/CMP.1 (Chapter 11);
2) on holding accounts ("emission reduction units" - ERUs, or "assigned amount units" - AAUs, or "removal units" - RMUs), as specified in section I.E of the annex to Decision 15/CMP.1 (Chapter 12);
3) on changes in the national system, in accordance with Article 5.1 of the Kyoto Protocol and as specified in section I.F of the annex to Decision 15/CMP.1 (Chapter 13);
4) on changes in the national registry, as specified in section I.G of the annex to Decision 15/CMP.1 (Chapter 14);
5) on minimization of adverse impacts, in accordance with Article 3.14 of the Kyoto Protocol and as specified in section I.H of the annex to Decision 15/CMP.1 (Chapter 15).

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, as well as supplementary information required pursuant to Article 7.1 of the Kyoto Protocol

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 Ministry of Ecology and Natural Resources of Ukraine 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 Resolution of the Cabinet of Ministers of Ukraine of July 16, 2012 No. 630). 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 Ministry of Ecology and Natural Resources of Ukraine of October 31, 2016 No. 404 «On Amendments to Order of the Ministry of Ecology and Natural Resources of Ukraine of April 26, 2016 No. 160», amendments were introduced that influenced the structure of the central apparatus of the Ministry of Ecology and Natural Resources of Ukraine, namely the Department of Climate Change 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 National Inventory Report 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.

Untill September 09, 2014, the State Environmental Investment Agency (SEIA) of Ukraine served as the only national body, that was responsible for preparation of the National Inventory Report 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 National Inventory Report. 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 Ministry of Ecology and Natural Resources of Ukraine. Consequently after amendments to the Ministry's apparatus by Order of the MENR of October 31, 2016 No. 404 the Department of Climate Change and Ozone Layer Protection was formed. The Department of climate policy functioned before the deadline in accordance with the order of the MENR of May 12, 2015 No. 147.

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 Ministry of Ecology and Natural Resources of Ukraine respective aggregated activity data for GHG inventory in accordance with the forms agreed with the Department of Climate Change and Ozone Layer Protection of MENR of Ukraine;
- 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 greenhouse gas 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;

- Ministry of Ecology and Natural Resources of Ukraine 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 Ministry of Ecology and Natural Resources of Ukraine provides is responsible for inventory of anthropogenic GHG emissions by sources and removals by sinks at the national level in order to prepare the National Inventory Report, as well as approval and submission to the UNFCCC Secretariat of the National Inventory Report. The Department of Climate Change and Ozone Layer Protection, as a structural unit of the Ministry of Ecology and Natural Resources of Ukraine according to the Order of MENR from October 31, 2016 No. 404.

Funding of preparation of the National Inventory Report is provided from the state budget of Ukraine.

Preliminary version of the National Inventory Report and the CRF-tables are published by the Ministry of Ecology and Natural Resources of Ukraine 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 National Inventory Report – revised and updated with regard to received recommendations – is submitted for consideration by the Inter-Agency Commission to ensure implementation of the UNFCCC in accordance with Resolution of the Cabinet of Ministers of Ukraine of April 04, 1999 of No. 583 with amendments (Resolution of the Cabinet of Ministers of August 12, 2015 of No. 616). As a result of consideration by the Inter-Agency Commission, the Ministry of Ecology and Natural Resources of Ukraine submits the official version of the National Inventory Report and CRF tables to the UNFCCC Secretariat.

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

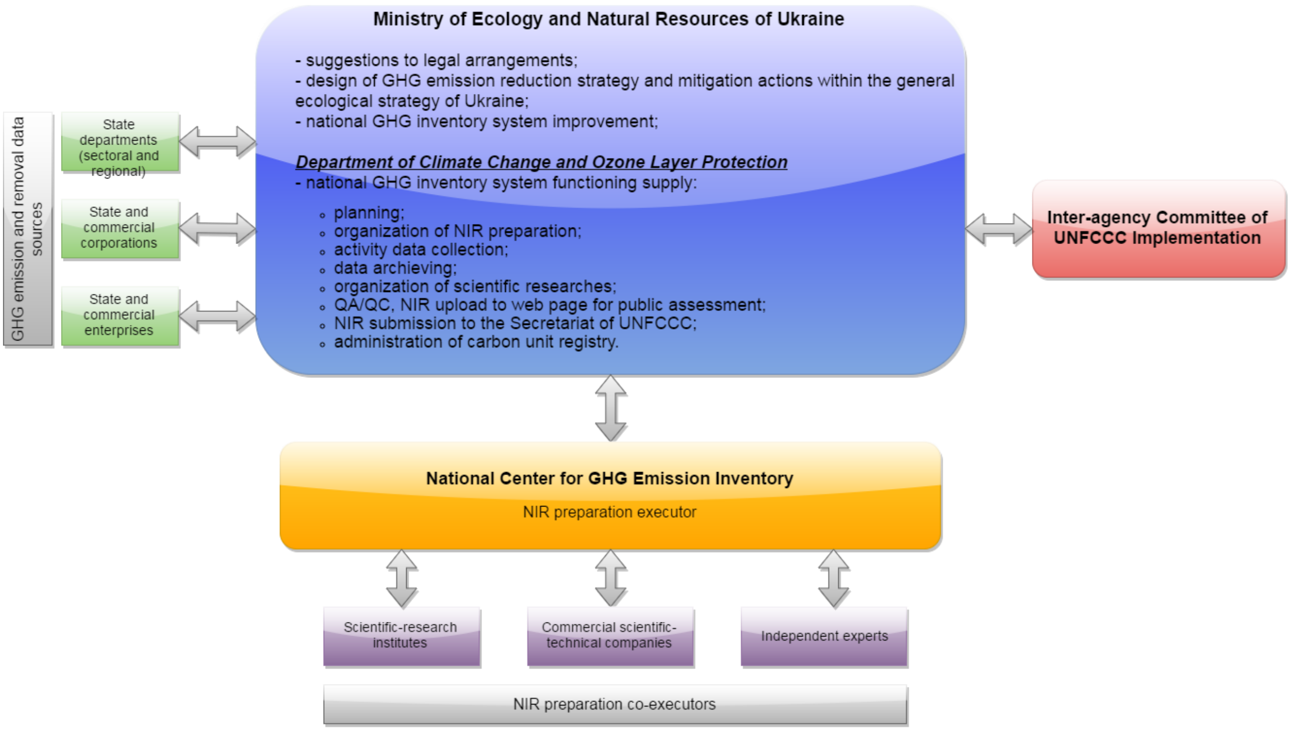

Fig. 1.9 Generalized diagram of the National Inventory System in Ukraine

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.

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 greenhouse gas emission and removals estimations and according to the Request on the submission of proposals to the prospective plans for 2016 from the MENR of Ukraine, in 2016 the experts of BI «NCI» (Budget Institution «National Center for GHG Emission Inventory») updated a list of necessary research projects (24 items). However, funding was not allocated due to difficult socio-economic situation in Ukraine.

During development of the current inventory, the methodological recommendations obtained in 2012-2013 as a result of 18 research projects were used, including those aimed at:

– reporting provision in order to implement requirements of the UNFCCC and KP;

– systemic analysis and modeling of functioning processes of the national anthropogenic greenhouse gas emission and removals estimation system, including legal aspects;

– development of calculation methods and determination of greenhouse gas emissions for different categories of sources.

During 2016-2017, 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:

– IPCC Expert Meeting to collect EFDB and Software users' feedback, Kobe, Japan, January 25-28, 2016;

– The first meeting of the Technical working group (TWG) on energy consumption in industry, housing and communal services, commercial and institutional sectors, Kyiv, May 24, 2016;

– The first meeting of the Technical working group (TWG) on waste management, Kiev, May 25, 2016;

– Training for accounting of greenhouse gas emissions the Center of accounting and research of greenhouse gas emissions, Seoul, Republic of Korea, July 04-26, 2016;

– The second meeting of the Technical working group (TWG) on energy consumption in industry, housing and communal services, commercial and institutional sectors, Kyiv, Ukraine, July 06, 2016;

– Training on the implementation and improvement of monitoring, reporting and verification of greenhouse gases emissions, Kyiv, September 26 – October 01, 2016;

– The Meeting on the draft DSTU "Liquid and gaseous biofuels. Greenhouse gas emissions", Kyiv, December 1, 2016;

– Seminar-training "Monitoring, reporting and verification of greenhouse gas emissions – the EU experience and lessons for Ukraine", Kyiv, December 5, 2016;

– IPCC Expert Meeting to collect EFDB and Software users' feedback, Kitakyushu, Japan, March 14-17, 2017;

– The Working meeting on discussion of the draft action plan for the implementation of "Concept of realization of state policy on climate change for the period to 2030", Kyiv, March 27, 2017;

– The Workshop "Improvement of national reporting on greenhouse gas emissions from road transport", Kyiv, March 30, 2017;

– The event "Implementation of Ukraine's international obligations on climate change and the introduction of market mechanisms in accordance with Directive 2003/87/EU", Kyiv, April 24, 2017;

– 1st Lead Autor Meeting (LAM1) for the Elaboration"2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories", Bilbao, Spain, June 12-14, 2017;

– The meeting of the Environmental Control and Transparency. Cook County Department of Environmental Control, Kyiv, June 14, 2017;

– 2nd Lead Autor Meeting (LAM2) for the Elaboration "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories", Victoria Falls, Zimbabve, September 25-28, 2017;

– The Workshop "Identification of indicators for the allocation of quotas for GHG emissions in Ukraine", Kyiv, October 10-11, 2017.

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

Quality Assurance and Quality Control (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 quality control 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 expert review team (ERT), authorized by the Secretariat of UN Framework Convention on Climate Change (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 quality control 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 quality control reporting forms.

In order to perform and taking account of the comments of the ERT, made at the time of verification of the Inventory (filing in 2015) revised and adopted action plan, in which special attention was paid to minimize the possibility of errors in calculations, according to Inventory data and CRF tables in all sectors.

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 National Inventory Report is presented in Fig. 1.10.

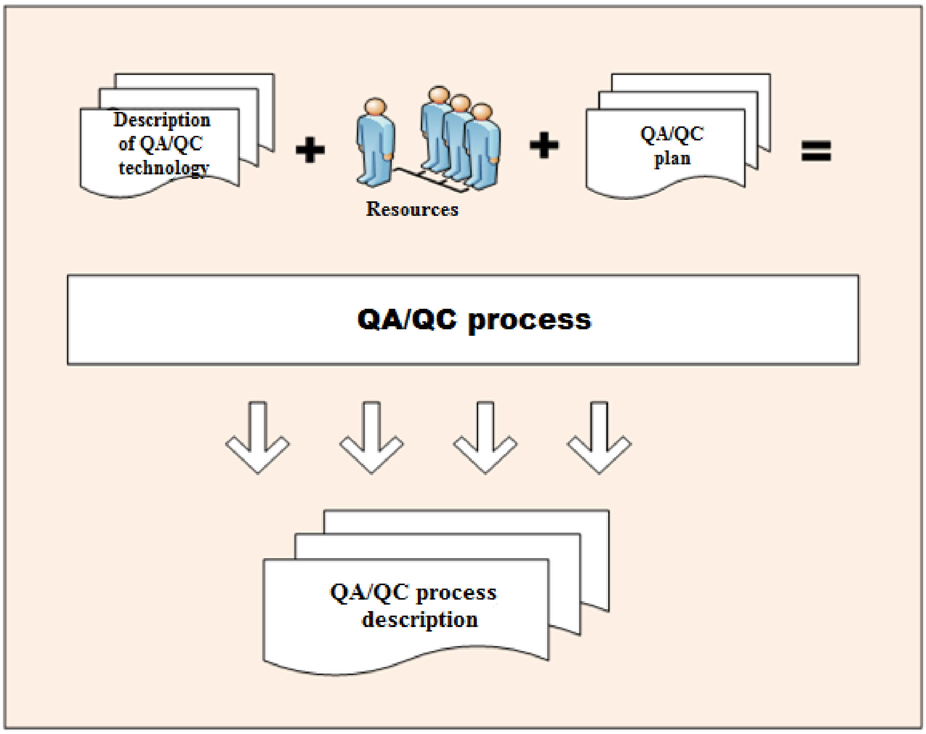

Fig. 1.10. The quality assurance/control system of the NIR

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

Quality control (QC) of the National Inventory Report takes place throughout the data collection, compilation, and reporting cycle. The data check system used in the National Inventory Report is illustrated in Figure 1.11.

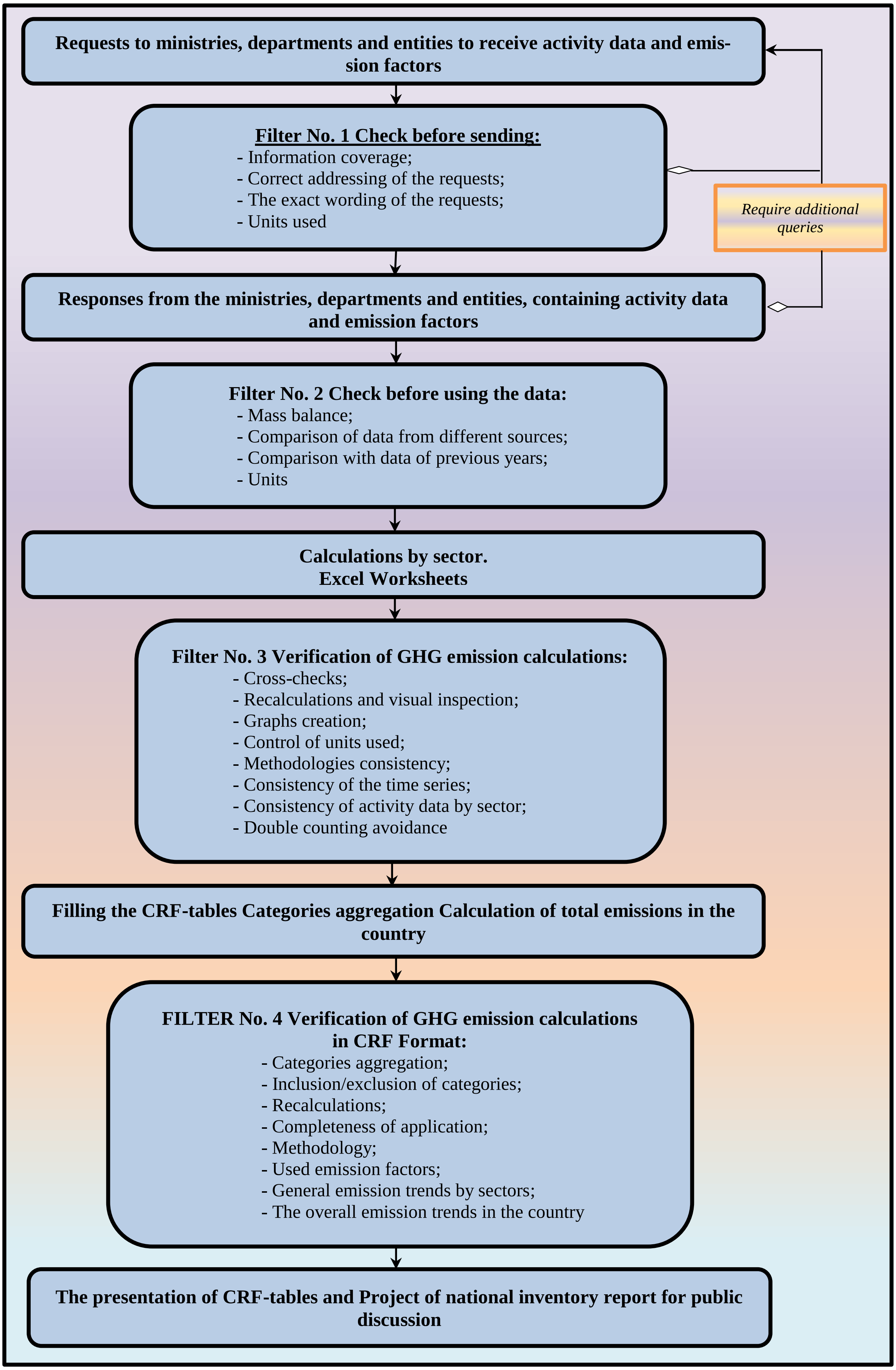

Figure 1.11. The general scheme of the quality assurance process

Checks and documentations are supported by data storage and processing designed specifically for National Inventory Report 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 National Inventory Report 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 National Inventory Report 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 quality control 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.

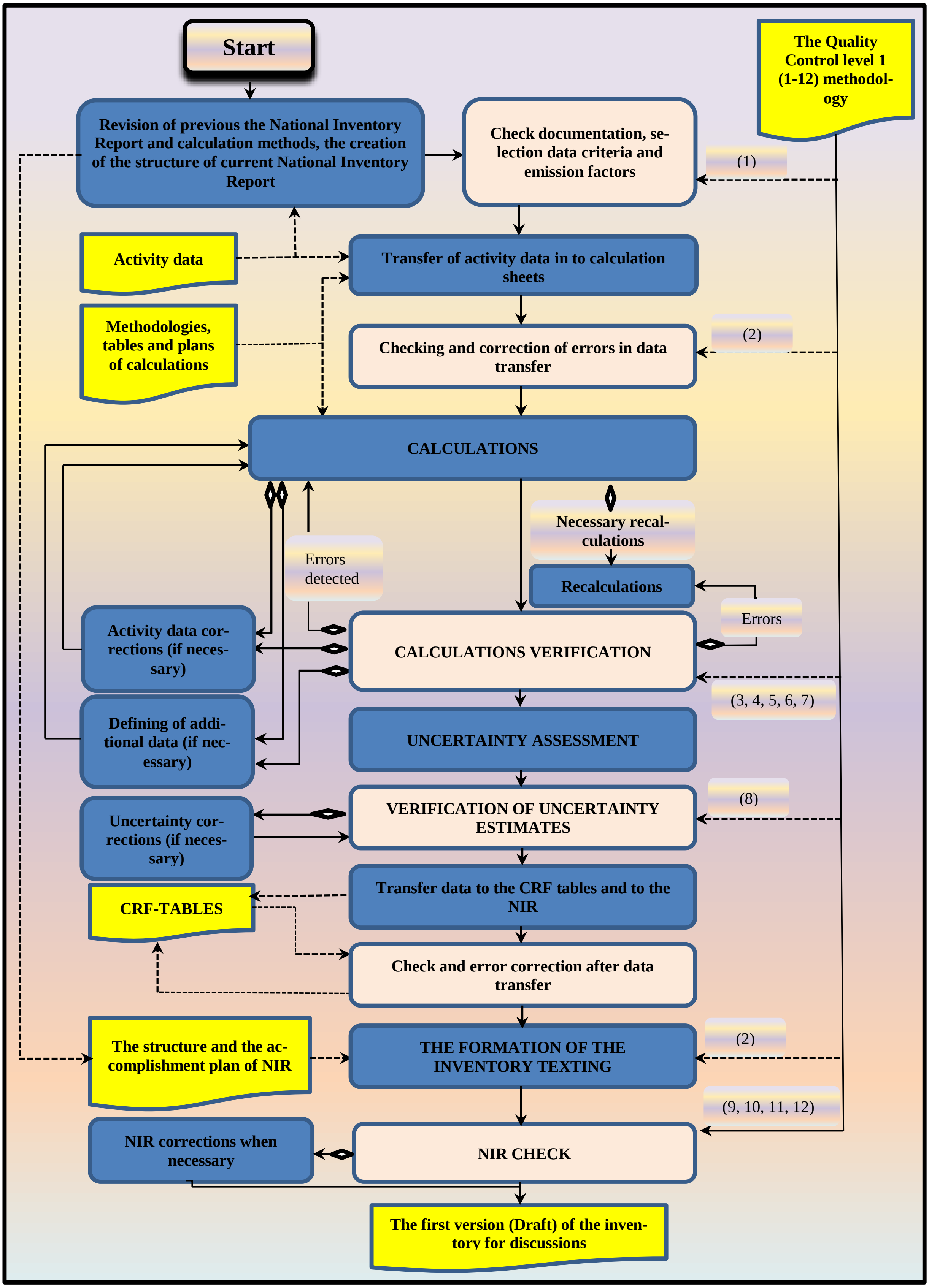

Figure 1.12. Diagram of general development and quality control processes

Quality control procedures were carried out during preparation of the National Inventory Report 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.

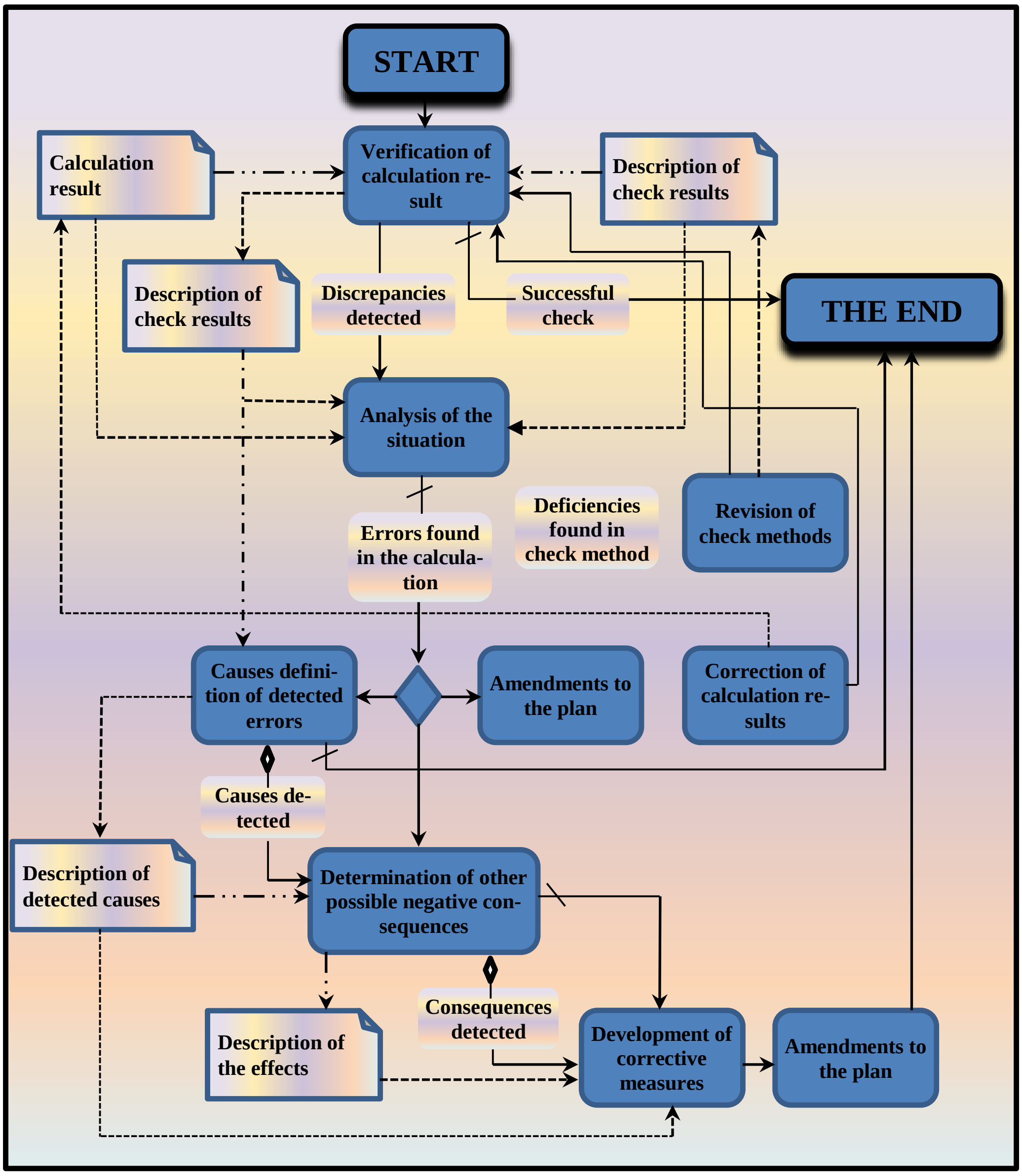

Figure 1.13. The diagram of the check result of analysis process

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)

Quality assurance (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 opinions, 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;
- Committee of the Verkhovna Rada of Ukraine on Environmental Policy, Nature Resources Utilization and Elimination of the Consequences of Chornobyl Catastrophe;
- National Security and Defense Council of Ukraine;
- Ministry of Agrarian Policy and Food of Ukraine;
- Ministry of Economic Development and Trade of Ukraine;
- Ministry of Energy and Coal Industry of Ukraine;
- Ministry of Foreign Affairs of Ukraine;
- Ministry of Infrastructure of Ukraine;
- Ministry of Education and Science of Ukraine;
- Ministry of Regional Development, Construction, and Communal Living of Ukraine;
- Ministry of Finance of Ukraine;
- National Academy of Sciences of Ukraine;
- State Water Resources Agency of Ukraine;
- State Agency on Energy Efficiency and Energy Saving of Ukraine;
- State Service of Geodesy, Cartography and Cadastre in Ukraine;
- State Forest Resources Agency of Ukraine;
- State Statistics Service of Ukraine;
- State Emergency Service of Ukraine;
- Ukrainian Hydrometeorological Institute, National Academy of Sciences and State Emergency Service of Ukraine;
- Public Organization «Bureau of complex analysis and forecasts «BIAF»;
- Institute of General Energy, National Academy of Sciences of Ukraine;
- State Enterprise «GosavtotransNIIproekt»;
- 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 Science of National Academy of Agrarian Sciences of Ukraine;
- Institute of Coal Energy Technologies of NAS of Ukraine;
- Institute for Energy Saving and Energy Management NTUU «KPI», Department of environmental engineering;
- National Scientific Center «Institute of Agriculture NAS of Ukraine»;
- State Institution «Scientific Centre for Aerospace Research of the Earth Institute of Geological Science National Academy of Sciences of Ukraine»;
- Odessa State Environmental University;
- Ukrainian Order «Badge of Honor» Research Institute of Forestry and agroforestry im. H.M. Vysotskoho;
- National Academy of Agrarian Sciences of Ukraine;
- Scientific Engineering Centre "Biomass".

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 Ministry of Ecology and Natural Resources of Ukraine website (http://www.menr.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.

The **Energy sector**. Within the QA procedures of the National Inventory Report the category 1.A "Fuel Combustion Activities" have been analyzed by experts of the Public Organization «Bureau of complex analysis and forecasts «BIAF», as reflected in the relevant review. Provided comments were taken into account, if possible.

The category 1.A.3.b "Road Transportation" have been analyzed by experts of the SE «GosavtotransNIIproekt», as reflected in the relevant review. Provided comments and suggestions were taken into account, if possible.

In the **Industrial processes and product use** sector**,** in line with requirements of 2006 IPCC Guidelines, data of the category Limestone and Dolomite Use is accounted under 2.C.1 Iron and Steel Production and 2.C.2 Ferroalloys Production categories. The Quality Control was conducted in accordance with QC procedures for these categories.

In category 2.C.1 Iron and Steel Production, a research work of the State Institution «State Environmental Academy of Postgraduate Education and Management» was used – «Development of the method to calculate and forecast greenhouse gas emissions at metallurgical enterprises of Ukraine». For category 2.C.2 Ferroalloys Production, a research work of the State Institution «State Environmental Academy of Postgraduate Education and Management» was used – «Development of guidelines for definition of emission factors by clarifying the composition of reductants used in production of ferroalloys, and carbon content in ore, slag-forming materials, and waste». The use of scientific research allowed to use the more accurate calculations level using national emission factors.

In category 2.F Product Uses as Substitutes for Ozone Depleting Substances, the research work of the State Enterprise «Cherkassy State Research Institute for technical and economic information in chemical industry» – «Methodology development and determination of emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride», which allowed to clarify the data on their use, export, and import by enterprises of Ukraine.

For category 2.C.1 Iron and Steel Production the review from SE «UkrRTC «Energostal» was received. In particular, it was noted that the work is done a qualitatively. Moreover several recommendations were provided, which will be considered, if possible, in the next NIR.

In **Agriculture** sector results of scientific researches were used, namely – «Development of the calculation methodology and determination of nitrous oxide emissions from agricultural soils: the final report on implementation of the 2nd (second) phase of the research project», «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».

The Agriculture sector received positive review from the National Scientific Centre «Institute of Agriculture of the National Academy of Agrarian sciences of Ukraine». In particular, it was noted that there is a need to conduct scientific experiment in order to develop national standards.

The **Land Use, Land-Use Change and Forestry** sector. The reviews from experts Lialko V. (Academician of NAS of Ukraine, Doctor of geology-mineralogical sciences, professor, Honoured Scientist of Ukraine) and Movchan D. (Candidate of geology sciences, Senior Researcher) of the State Institution «Scientific Centre for Aerospace Research of the Earth Institute of Geological Science National Academy of Sciences of Ukraine» was received on the **Land Use, Land-Use Change and Forestry** sector. Provided suggestions were taken into account, if possible.

The review from Odessa State Environmental University was received on the Land Use, Land-Use Change and Forestry sector regarding the correctness of the calculations in the categories 4.B Cropland and 4.C Grassland and its accordance to the methodology. In particular it is mentioned «After review of methodology used for Ukrainian conditions, as well as activity data and correctness of calculations performed based on this methodology, no significant errors were found. The calculations are performed in accordance with accepted methodology». However the comment was made that, if possible, will be considered in the next NIR.

Within the QA procedures NIR have been analyzed by experts of the Ukrainian Order «Badge of Honor» Research Institute of Forestry and Agroforestry im. H.M. Vysotskoho. In particular, a high scientific and methodological level of performance was noted and some adjust-ments that, where possible, were taken into account were provided.

Inter-Agency Commission

The Inter-Agency Commission on Implementation of the United Nations Framework Convention on Climate Change (IAC) was established by Resolution of the Cabinet of Ministers of Ukraine in April 14, 1999 No. 583 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.

The key tasks of IAC include: organization of preparation of the National Inventory of anthropogenic emissions by sources and absorption by sinks of all greenhouse gases not controlled by Montreal Protocol on Ozone Layer Depleting Substances; organization of preparation of national communications on compliance with the obligations under the UNFCCC; development of proposals for implementation of KP commitment implementation mechanisms; coordination of ministries and other central and local executive bodies, enterprises, institutions and organizations regarding implementation of the national action plan for implementation of Ukraine's commitments under the UNFCCC and KP; consideration of reporting documents to be submitted to the UNFCCC Secretariat, draft directives for official government delegations and representatives of the Cabinet of Ministers of Ukraine at international events on climate change, etc.

According to the existing legal documents, namely Decree of the Cabinet of Ministers of Ukraine of April 14, 1999 No. 583 with the latest amendments from 12.08.2015 No. 616, the IAC shall include:

- Minister of Ecology and Natural Resources of Ukraine – Chairman of the Commission
- Deputy Minister of Ecology and Natural Resources of Ukraine – First Deputy Chairman of the Commission;
- Deputy Minister of Economic Development and Trade of Ukraine – Head of Staff -deputy Chairman of the Commission;
- First Deputy Minister of Energy and Coal Industry of Ukraine – Deputy Chairman of the Commission;
- head of the structural unit of the Ministry of Ecology and Natural Resources of Ukraine responsible for ensuring development and implementation of the state policy for UNFCCC commitments implementation – Secretary of the Commission;
- Deputy Minister of Foreign Affairs of Ukraine – Head of Staff;
- Deputy Minister of Finance of Ukraine – Head of Staff;
- Deputy Minister of Agrarian Policy and Food of Ukraine – Head of Staff;
- Deputy Minister of Infrastructure of Ukraine – Head of Staff;

– Deputy Minister of Education and Science of Ukraine – Head of Staff;
– Deputy Minister of Regional Development, Construction, Housing and Communal Living of Ukraine;
– Deputy Secretary of the National Security and Defense Council of Ukraine (if agreed);
– Deputy Chairman of the State Service of Geodesy, Cartography and Cadastre of Ukraine;
– Deputy Chairman of the State Forest Resources Agency of Ukraine;
– Deputy Chairman State Statistic Service of Ukraine;
– Chairman of the Verkhovna Rada Committee on Environmental Policy, Natural Resources and Elimination of Consequences of Chornobyl Catastrophe (if agreed);
– representative of the Secretariat of the Cabinet of Ministers of Ukraine;
– upon the agreement – representatives of public authorities, local governments, academic institutions, non-governmental organizations, deputies of Parliament 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 Ministry of Ecology and Natural Resources of Ukraine 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.

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. 7, p. 2 of Resolution of the Cabinet of Ministers of Ukraine of September 10, 2014 No. 442 «On the Optimization of the Central Executive Power», 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 United Nations Framework Convention on Climate Change and Meetings of the KP Parties is the Ministry of Ecology and Natural Resources of Ukraine, which is guided and coordinated by the Cabinet of Ministers of Ukraine. One of the structural units of the Ministry of Ecology and Natural Resources of Ukraine is the Department of Climate Change and Ozone Layer Protection, created by the order MENR of October 31, 2016 No. 404, 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 Ministry of Ecology and Natural Resources of Ukraine 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 National Inventory Report 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 National Inventory Report (draft of National Inventory Report) 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 Ministry of Ecology and Natural Resources of Ukraine and to obtain comments and suggestions from stakeholders and independent experts.
12. Further development of the draft National Inventory Report with regard to comments received.
13. Preparation of the final version of the National Inventory Report.
14. Provision of the National Inventory Report for consideration of the Inter-Agency Commission.

15. Submission of the National Inventory Report by the Ministry of Ecology and Natural Resources of Ukraine to the UNFCCC Secretariat.

16. Documentation and archiving of all data used in preparation of the National Inventory Report.

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

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

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

In line with the information presented paragraph 1.2.3.1 "QA/QC procedures", planning development of the National Inventory Report to be submitted in 2018 is covered in internal use documents based on typical annual inventory preparation plans and inventory Quality Assurance and Quality control activities, approved by Order of the Ministry of Environmental Protection of May 31, 2007 No. 268, namely:

1) 2017-2018 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 1990-2016;

2) 2017-2018 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 1990-2016 (submitted in 2018).

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

1.4.1 Greenhouse gas inventory

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

CRF cate-gory	Name of the emission category	Comment on the method applied
1.A.3	Transport	T1, T2, T3
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, T2, 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, T2
2.G	Other product manufacture and use	CS, T2,T3
2.H	Other	EMEP/EEA
3.A	Enteric Fermentation	T1, T2, T3
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
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. Use of limestone in agriculture and for production of sugar, soda, and cement. Iron consumption for steel industry. 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.

Name of the data source	Name of the activity data
	Amount of wool produced per sheep. Gross harvesting, yield, and total harvested area of agricultural crops. Amount of nitrogen and organic fertilizers applied into the soil in Ukraine by regions. Grouping of agricultural enterprises by presence of livestock. Volumes of non-energy peat production for agriculture. Volume of timber harvesting, production, import, and export. Harvesting area in forestry (including harvesting types according to their destination by regions). Fire areas and consequently damaged wood in the forests of Ukraine. Number of total and urban populations. Information about the total area of forests and areas covered with forest vegetation in Ukraine. 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 and Coal Industry of Ukraine	Technical and economic indicators of CHP operation. Information about the coal industry of Ukraine. Information about the oil and gas system of Ukraine.
State Agency of Ukraine for Management of Public Corporate Rights and Property	Production, import, and export of industrial products. Data of carbon content in coke, pig iron, and steel.
Ministry of Agrarian Policy and Food 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
Ministry of Defense 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 on fuel consumption for the needs of the Ministry of Defence.
State Emergency Service 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.
Industrial enterprises	Data of chemical, metallurgy, cement, ceramics, glass production, as well as data on use of hydrofluorocarbons and sulfur hexafluoride.
Ministry of Regional Development, Construction, and Communal Living of Ukraine	Data on the volume of solid municipal waste delivered to landfill. Structure of Municipal Solid Waste management. Information on the status of sanitary treatment of settlements. Volumes of fuel consumption by the municipal sector.
State Water Resources Agency of Ukraine	Data on volumes of wastewater locally treated by industries. Data on volumes of household wastewater. Sewage sludge. Structure of wastewater treatment. Data on the area of cultivated peat soils.
State Enterprise «Cherkassy State Research Institute for technical and economic information in chemical industry»	Chemical production data
Ministry of Ecology and Natural Resources of Ukraine	The amount and composition of waste incinerated at waste incineration plants in Ukraine. Data on methane recovery from landfills. Data on the morphology and density of waste. Data 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.
Ministry of Infrastructure 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.
State Service of Geodesy, Cartography and Cadastre in Ukraine	Reporting data on quantitative accounting of land in Ukraine, including the report on availability of land and land distribution among owners, by type of land use and economic activity. Land Registry in Ukraine.
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. Volumes of wood harvested in 1961-1992.
Territorial Public Administration	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 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.
Ukrainian Research Institute of Civil Protection (UkrRICP)	Data on fires on grassland.

Name of the data source	Name of the activity data
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.

1.4.2 KP-LULUCF inventory

In preparation of additional information on outcomes of activities under paragraphs 3 and 4, Article 3 of Kyoto Protocol, methods and assumptions identical to those used for GHG inventory in the land-use category Forest Land were used for all carbon pools (except for mineral soils in managed forests) and all sources of GHG emissions. The basis for the assumption on mineral soils in forests is the research project [13], which is consistent with IPCC requirements. Identical data sources were used for the calculations. To maintain the time series of activity data in the land-use category Forest Land, in accordance with the methodological guidelines, continues to update the database of activity data with characteristics of activities regulated by paragraph 3 Article 3 of Kyoto Protocol.

In addition, due to national practice of accounting of lands of the State Service of Geodesy, Cartography and Cadastre in Ukraine, during the inventory taken into account 7-year-old step which is applied to the territories covered with forest vegetation [14].

1.5 Brief description of key categories, including KP-LULUCF

1.5.1 Greenhouse gas inventory

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 2016 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 (2016)

IPCC source category		Gas	Level	Trend
A		B	D	E
1.A.1	Fuel combustion - Energy industries - Liquid fuels	CO_2	+	+
1.A.1	Fuel combustion - Energy industries - Solid fuels	CO_2	+	+
1.A.1	Fuel combustion - Energy industries - Gaseous fuels	CO_2	+	+
1.A.1	Fuel combustion - Energy Industries - Other Fossil 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.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous 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.3.c	Railways	CO_2		+
1.A.4	Other sectors - Liquid fuels	CO_2		+
1.A.4	Other sectors - Solid fuels	CO_2		+
1.A.4	Other sectors - Solid fuels	CH_4		+
1.A.4	Other sectors - Gaseous 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.C.1	Iron and Steel Production	CO_2	+	+
2.C.2	Ferroalloys Production	CO_2	+	

IPCC source category		Gas	Level	Trend
A		B	D	E
3.A	Enteric Fermentation	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	+	+
5.A	Solid Waste disposal	CH_4	+	+
5.D	Wastewater Treatment and Discharge	CH_4	+	+

Table 1.5. Key category analysis, including LULUCF sector (2016)

IPCC source category		Gas	Level	Trend
A		B	D	E
1.A.1	Fuel combustion - Energy industries - Liquid fuels	CO_2	+	+
1.A.1	Fuel combustion - Energy industries - Solid fuels	CO_2	+	+
1.A.1	Fuel combustion - Energy industries - Gaseous fuels	CO_2	+	+
1.A.1	Fuel combustion - Energy Industries - Other Fossil 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.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous 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 - Liquid fuels	CO_2		+
1.A.4	Other sectors - Solid fuels	CO_2		+
1.A.4	Other sectors - Gaseous 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	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.C.1	Iron and Steel Production	CO_2	+	+
2.C.2	Ferroalloys Production	CO_2	+	
3.A	Enteric Fermentation	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	+	+
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.C.1	Grassland remaining Grassland	CO_2		+
4.D.1.1	Peat Extraction remaining Peat Extraction	CO_2		+
4.G	Harvested Wood Products (HWP)	CO_2		+
5.A	Solid Waste disposal	CH_4	+	+
5.D	Wastewater Treatment and Discharge	CH_4	+	+

1.5.2 KP-LULUCF inventory

In determining the key categories methodological recommendations of 2006 IPCC were applied. The categories directly related with KP activities are the following: Forest Land remaining Forest Land, Land converted to Forest Land and Forest Land converted to other land uses. According to reporting under the UNFCCC, category 4.A.1 is the key. GHG inventory in AR and D categories resulted in lower emissions/reductions, that the lowest key category.

Table 1.6. Findings of key category analysis of activities under paragraphs 3 and 4, Article 3 of the Kyoto Protocol in 2016

Specification of the key category according to the national disaggregation level	Gas	Criteria used for identifying key categories			Comments
		Corresponding key category	Confirmation of exceeding by the selected category of the lowest key one under the inventory, in accordance with UNFCCC requirements (including LULUCF)	Other	
Forest management	CO_2	4.A.1 Forest Land remaining Forest Land	Yes		The relevant categories were identified as key in the GHG inventory in accordance with UNFCCC requirements. Results of the GHG inventory in the specified categories exceed the value of the lowest in the list of key categories.
Afforestation and Reforestation	CO_2	4.A.2 Land converted to Forest Land	No		The relevant categories were not identified as key in the GHG inventory in accordance with UNFCCC requirements. Results of the GHG inventory in the category do not exceed the value of the lowest in the list of key categories.
Deforestation	CO_2	Forest land converted to other land uses	NO		The relevant categories were not identified as key in the GHG inventory in accordance with UNFCCC requirements. The sum of results of the GHG inventory in the specified categories do not exceed the value of the lowest in the list of key categories.

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

1.6.1 Uncertainty of the GHG Inventory

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

The results indicate that the net emissions in 2016 year including the sector Land use, land-use change and forestry (LULUCF) is 321283.38 kt CO2 equivalent with an uncertainty of 10.69 %; excluding the LULUCF sector – 339278.05 kt CO2 equivalent with an uncertainty of 7.63 %. Based on totals of years 1990 and 2016, the average trend including the LULUCF sector is 63.85 % reduction of emissions; excluding the LULUCF sector – 64.16 % reduction of emissions. The uncertainty of the trend including the LULUCF sector is 3.06 %; excluding the LULUCF sector – 1.68 %.

For more detailed information see Tables A7.1-A7.2 of Annex 7.

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 2016, %	The percentage uncertainties of the emissions for 2016 %
Energy	81.61	70.48	2.85
Industrial processes and product use	13.21	18.06	0.51
Agriculture	10.35	13.21	7.37
LULUCF	-6.52	-5.60	7.02
Waste	1.34	3.85	1.51

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 2016, %	The percentage uncertainties of the emissions for 2016, %
Energy	76.61	66.74	2.70
Industrial processes and product use	12.41	17.11	0.49
Agriculture	9.72	12.51	6.98
Waste	1.26	3.64	1.43

The lowest percentage of emissions uncertainty in 2016 year is observed in the Industrial processes and product use sector.

1.6.2 Uncertainty of KP-LULUCF

Uncertainty level for calculation results in KP-LULUCF is estimated based on use of the same uncertainties of AD and EFs as for LULUCF sector. which are related to activities in forestry. Overall uncertainty value regarding carbon removals on afforestation lands is equal to 39 %. considering uncertainties of carbon removals by litter 38 %. for soils – 29 %.

1.7 General assessment of completeness

1.7.1 Completeness assessment of GHG inventory

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, 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, 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, 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, 2.B.1 Ammonia Production, 3.B.2.5 Indirect N_2O Emissions, 4.A.2.3 Wetlands converted to forest land, 4.D.1 Wetlands Remaining Wet-lands/4(V) Biomass Burn-ing/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 **(NOx)** 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.AA Fuel Combustion - Sectoral approach/Information item/ (biomass, fossil fuels), 1.AB Fuel Combustion - Reference Approach / Solid Fuels / Anthracite, Coking Coal, 1.B.2.c.1.ii Gas, 1.B.2.c.1.iii Combined, 1.B.2.c.2.iii Combined, 1.AD Feedstocks, reductants and other non-energy use of fuels / Liquid fossil / 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, 5.C.1.2.a Municipal Solid Waste, 5.C.1.2.b Other (please specify)/Clinical Waste, Industrial Solid Wastes;
- 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, 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 Burn-ing/Wildfires; 5.C.1.2.a Municipal Solid Waste, 5.C.1.2.b Other (please specify)/Clinical Waste, Industrial Solid Wastes.

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 greenhouse gas emissions included in the inventory but not presented separately for this category.

1.7.2 Completeness assessment for KP-LULUCF

Regarding applications in the CRF-table, the aforementioned notation keys and the reasons listed in paragraph 1.7.1 in sector KP-LULUCF should be taken into account that, according to article 3.4 of the Kyoto Protocol, no additional activities in addition to obligatory forest management has been selected.

IE were used in the following cases:

- the loss of below-ground biomass in Afforestation areas harvested from the beginning of the commitment period; GHG emissions from below-ground biomass accounted for in the emissions of above-ground biomass;
- the loss of below-ground biomass in the category forest management; GHG emissions from below-ground biomass accounted for in the emissions of above-ground biomass.

Detailed information on the categories of KP-LULUCF, not estimated by GHG inventory can be found in table 2 of Annex 5.

* 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

Dynamics of GHG emissions demonstrate the trend, which may be considered in five phases over the period of 1990-2016. 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 temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol as well as the Russian Federation military aggression in certain areas of the Donetsk and Luhansk regions, 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 Autonomous Republic of Crimea and the city of Sevastopol, occupied territories in the certain territories of Donetsk and Luhansk regions with industries of other regions in the country. In recent 2016 year emissions in all sectors (except LULUCF) increased, what is seen as recovery of economy of Ukraine from previous declines in economy.

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. Emissions of PFCs, HFCs, the SF_6 and NF_3 are not shown in the diagram, because the share of first three gases in total emissions amounted to 0.3% in 2016, and NF_3 emissions in Ukraine do not occur.

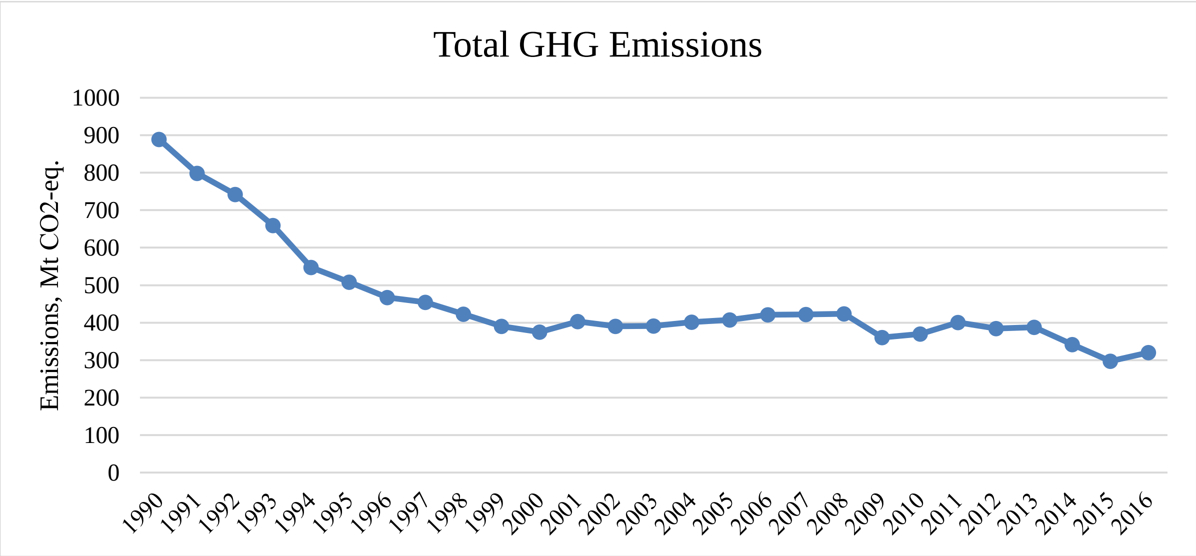

Fig. 2.1. GHG emissions in Ukraine (including LULUCF), 1990-2016, Mt CO_2-eq.

The largest share of GHG emissions in 2016 is carbon dioxide - 67.7 % including LULUCF. Methane emissions in 2016 were 21.5 %, and those of nitrous oxide - 10.8 %. In 1990, the proportion was 72.8 %, 21.3 %, and 5.8 % for carbon dioxide, methane, and nitrous oxide, respectively.

[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 LULUCF	705.8	632.5	589.1	510.2	419.3	389.9	351.4	340.2	321.1	292.3	279.5	301.3	294.2
CO_2 emissions with net CO_2 from LULUCF	647.6	569.7	527.6	456.8	360.9	336.7	303.3	295.6	269.8	240.2	233.9	260.6	254.8
CH_4 emissions without CH_4 from LULUCF	189.4	181.5	171.3	162.5	152.2	140.5	136.4	130.6	127.9	127.6	118.6	118.0	110.8
CH_4 emissions with CH_4 from LULUCF	189.4	181.5	171.3	162.5	152.3	140.6	136.5	130.6	127.9	127.7	118.6	118.0	110.8
N_2O emissions without N_2O from LULUCF	51.8	46.7	42.7	39.8	34.2	30.7	26.7	27.3	24.5	22.3	22.3	23.8	24.4
N_2O emissions with N_2O from LULUCF	52.0	46.9	42.9	40.0	34.5	31.0	27.0	27.6	24.8	22.6	22.6	24.1	24.7
HFCs*	NO	NO	NO	NO	NO	NO	NO	6.43	13.02	14.14	15.75	29.04	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)	947.3	860.9	803.2	712.6	605.9	561.3	514.7	498.2	473.6	442.4	420.5	443.3	429.6
Total (with LULUCF)	889.3	798.3	742.0	659.5	547.8	508.5	466.9	453.9	422.6	390.6	375.1	402.9	390.5
Total (without LULUCF, with indirect)	947.3	860.9	803.2	712.6	605.9	561.3	514.7	498.2	473.6	442.4	420.5	443.3	429.6
Total (with LULUCF, with indirect)	889.3	798.3	742.0	659.5	547.8	508.5	466.9	453.9	422.6	390.6	375.1	402.9	390.5
Net CO_2 from LULUCF	-58.0	-62.6	-61.2	-53.1	-58.0	-52.8	-47.8	-44.3	-51.0	-51.8	-45.4	-40.4	-39.1

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO_2 emissions without net CO_2 from LULUCF	305.2	306.3	313.5	332.8	336.6	325.7	277.2	293.5	307.1	303.7	296.1	256.6	223.6
CO_2 emissions with net CO_2 from LULUCF	257.9	268.4	277.3	292.1	293.6	297.0	245.8	256.2	279.9	270.1	275.0	236.3	201.3
CH_4 emissions without CH_4 from LULUCF	110.9	108.3	104.8	102.8	102.1	95.5	87.4	86.7	88.0	82.6	77.5	70.9	63.3
CH_4 emissions with CH_4 from LULUCF	110.9	108.3	104.8	102.8	102.2	95.6	87.4	86.7	88.0	82.7	77.5	71.0	63.3
N_2O emissions without N_2O from LULUCF	21.8	24.2	24.7	25.1	24.8	29.6	25.7	26.3	31.9	30.6	33.8	33.7	31.4
N_2O emissions with N_2O from LULUCF	22.1	24.5	25.0	25.4	25.2	30.0	26.1	26.5	32.0	30.8	34.0	33.8	31.5
HFCs*	105.22	187.31	285.17	402.41	561.22	647.48	663.94	744.09	820.40	841.34	881.85	848.40	775.59
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	8.41	10.99	12.54	16.73	19.40
NF_3*	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total (without LULUCF)	438.0	439.0	443.5	461.2	464.2	451.7	391.0	407.3	427.8	417.8	408.3	362.0	319.0
Total (with LULUCF)	391.1	401.4	407.6	420.9	421.6	423.4	360.0	370.2	400.8	384.4	387.4	342.0	296.9
Total (without LULUCF, with indirect)	438.0	439.0	443.5	461.2	464.2	451.7	391.0	407.3	427.8	417.8	408.3	362.0	319.0
Total (with LULUCF, with indirect)	391.1	401.4	407.6	420.9	421.6	423.4	360.0	370.2	400.8	384.4	387.4	342.0	296.9
Net CO_2 from LULUCF	-46.9	-37.5	-35.9	-40.3	-42.6	-28.3	-31.0	-37.1	-27.0	-33.4	-20.9	-20.1	-22.1

	2016
CO_2 emissions without net CO_2 from LULUCF	235.2
CO_2 emissions with net CO_2 from LULUCF	217.0
CH_4 emissions without CH_4 from LULUCF	68.0
CH_4 emissions with CH_4 from LULUCF	68.0
N_2O emissions without N_2O from LULUCF	34.6
N_2O emissions with N_2O from LULUCF	34.7
HFCs*	889.00
PFCs*	NO
SF_6*	24.11
NF_3*	NO
Total (without LULUCF)	338.6
Total (with LULUCF)	320.6
Total (without LULUCF, with indirect)	338.6
Total (with LULUCF, with indirect)	320.6
Net CO_2 from LULUCF	-18.0

*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 1990-2016 in Ukraine. CO_2 emissions with LULUCF in 2016 amounted to 217.03 Mt, what is approximately 3 times lower compared with 1990 (647.63 Mt).

CO_2 emissions in the Energy sector in 2016 amounted to 180.09 Mt, what is 69.6 % lower than the value in the base year. In 1990, CO_2 emissions were 592.25 million tons and by 67.2 % consisted of emissions from fuel combustion compared to total emissions in the country. Such structure of CO_2 emissions is due to the high energy intensity of the economy. The economic decline that followed the collapse of the Soviet Union led to a significant reduction in energy consumption and CO_2 emission reduction in the energy sector in the period from 1990 to 2016.

Carbon dioxide emissions in IPPU sector in 2016 amounted to 54.46 Mt, what is 50.8 % lower than the value in the base year and 2.05% higher than the value in 2015. The largest source of CO_2 emissions in the IPPU sector is the Iron and steel production that amounts to 79% of total CO_2 emissions in sector. CO_2 emissions in sector in the period from 1990 to 2016 have decreased significantly due to a reduction in production output caused by the collapse of the USSR.

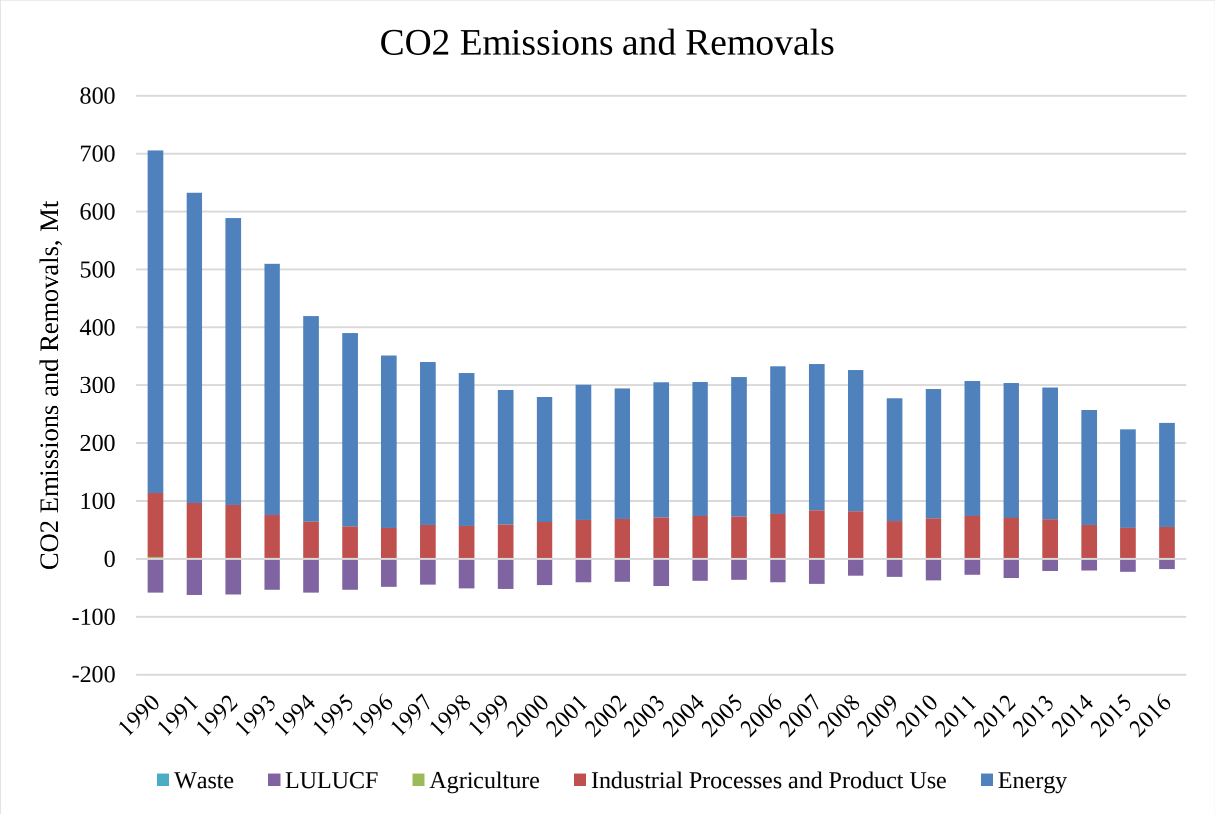

Fig. 2.2. Emissions and sinks of carbon dioxide by sector in Ukraine, 1990-2016, Mt

2.1.2 Methane emissions

Emissions of CH_4 are second largest after CO_2 if considering their share in total GHG emissions. In 2016, CH_4 emissions in Ukraine amounted to 67.99 Mt CO_2-eq. Compared to 1990, when the emissions were 189.44 Mt CO_2-eq., the emissions decreased by 64.1 %. In the last reporting year, the most significant source of methane emissions was the Energy sector - 65.0 %, and significant emissions were observed in Agriculture (17.5 %) and Waste (16.5 %) as well. In the base year, the Energy and Agriculture sector larger contribution to the emissions (67.5 % and 26.3 % respectively), while Waste had lower value - 5.4 %.

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 almost 3 times - from 127.47 to 45.96 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 2016 to 475.95 kt, what is around four times lower than the same indicator 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 approximately 23.0 %, and emissions from waste water decreased by 23.1 %.

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 period of 1990-2016 decreased from 55.73 to 25.87 kt (by 53.6 %) due to reduced production volumes. Emissions of CH_4 from LULUCF on average for the period of 1990-2016 accounted for less than 0.1% of the total methane emissions (see Fig. 2.3).

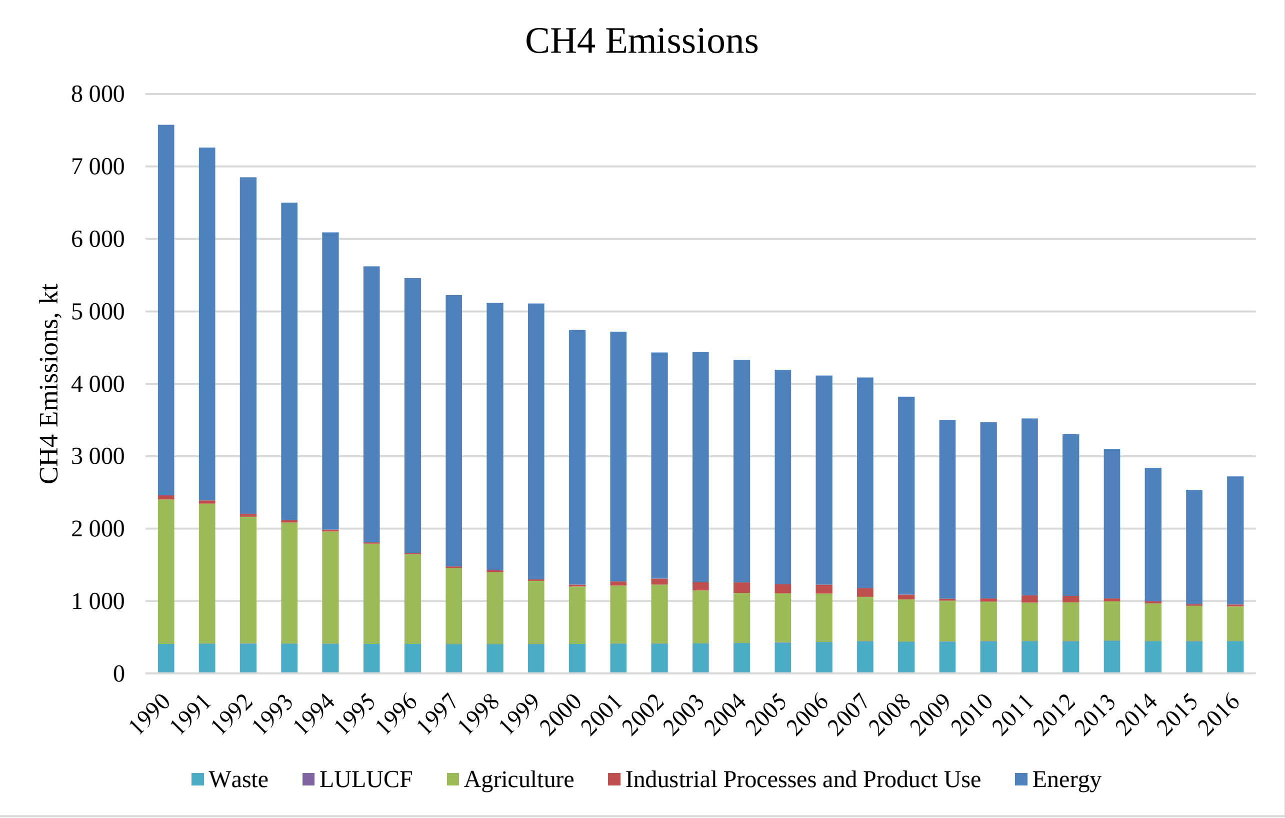

Fig. 2.3. Methane emissions in Ukraine by sector, 1990-2016, kt

2.1.3 Emissions of nitrous oxide

Nitrous oxide emissions in Ukraine in 2016 amounted to 34.7 Mt CO_2-eq., which is lower than in 1990 by 33.2 % (52.0 Mt CO_2-eq.). Compared with 2015, emissions of nitrous oxide increased by 10.1 %. The largest source of nitrous oxide emissions in Ukraine, as in the previous submissions, is the Agriculture sector - 86.3 % of total nitrous oxide emissions in 2016. 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 - 5.8 % of the totals in 2016. 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.

Moreover, N_2O emissions occur in the Energy sector (2.6 %), Waste (3.0 %), as well as small quantities in LULUCF (0.3%).

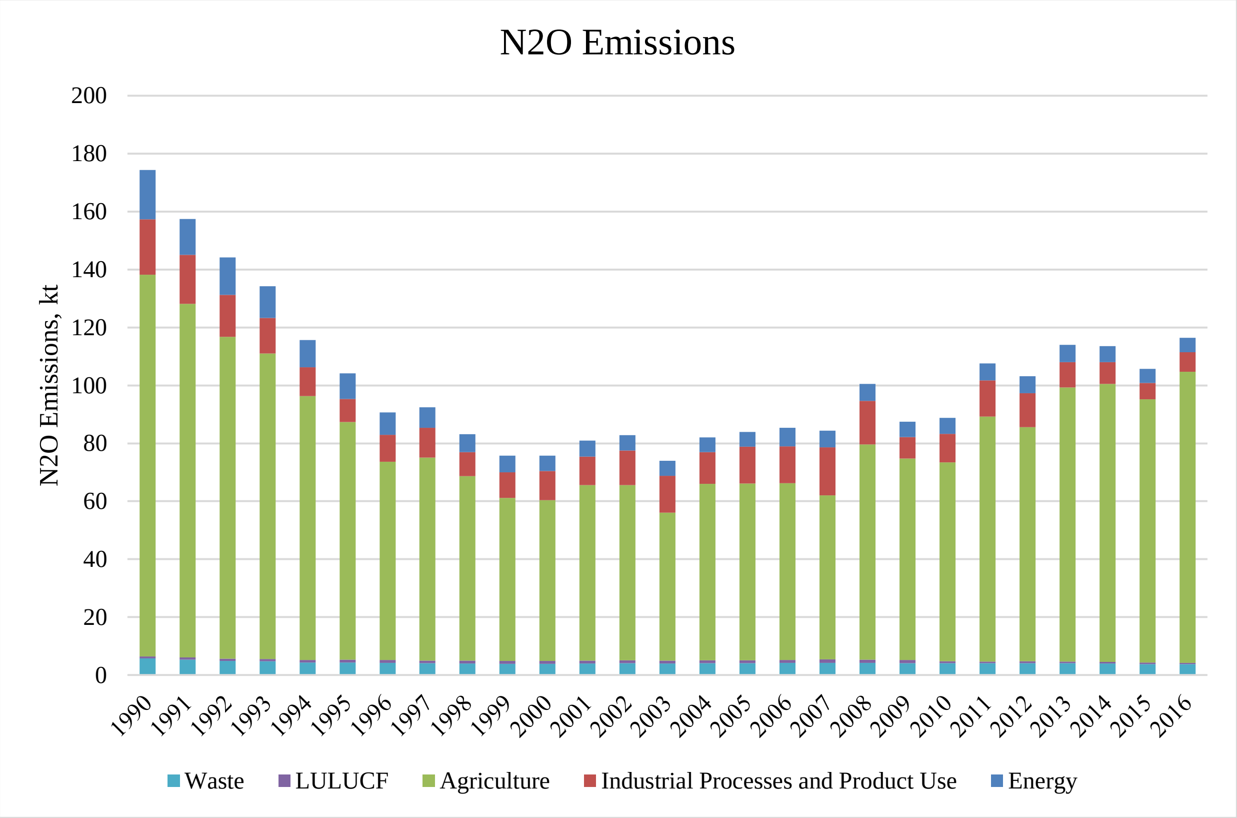

Fig. 2.4. Nitrous oxide emissions in Ukraine by sector, 1990-2016, kt

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

Emissions of HFCs, PFCs, SF6, and NF3 in Ukraine are not much significant in terms of volumes in comparison with total GHG emissions (0.3% of the total emissions in 2016). 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 SF6 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 SF6 in 1990 amounted to 235.82 and 0.01 kt CO2-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 SF6 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 2016 after the decreasing trend in 2014 – 2015 explains by recovery of economy of Ukraine from previous declines that resulted in growth of import of HFCs-contained equipment.

In 2016, there were no PFCs imports to Ukraine since there was no production need for it. Thus, PFCs emissions in 2016 are zero.

There are no emissions of NF3 due to absence of activities related to production of photovoltaic elements in Ukraine, according to data obtained from the companies that use photovoltaic elements in their production processes.

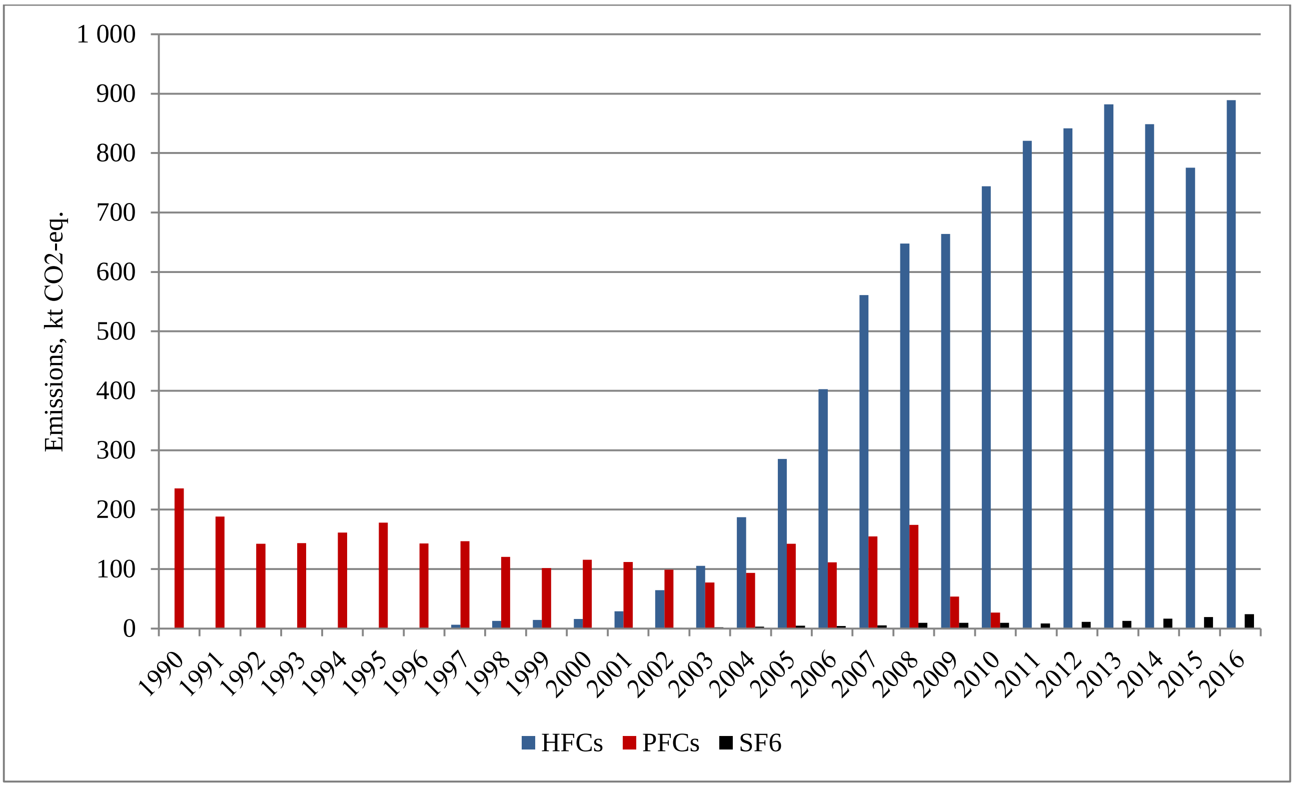

Fig. 2.5. Emissions of PFCs, HFCs and SF_6 in Ukraine, 1990-2016, kt CO_2-eq.

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 1990-2016. 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 (about 4% of the total), 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 1990-2016 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.

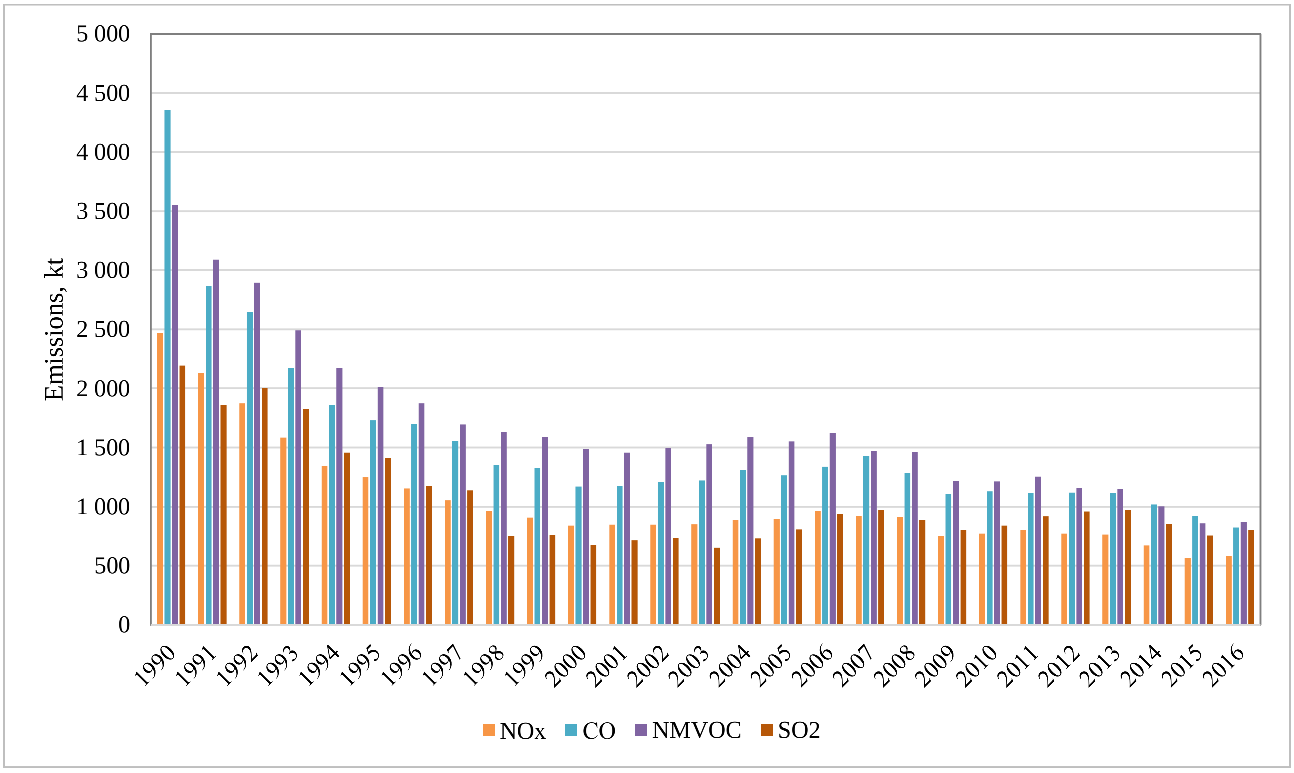

Fig. 2.6. Precursor and SO_2 emissions in Ukraine, 1990-2016, kt

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 2016.

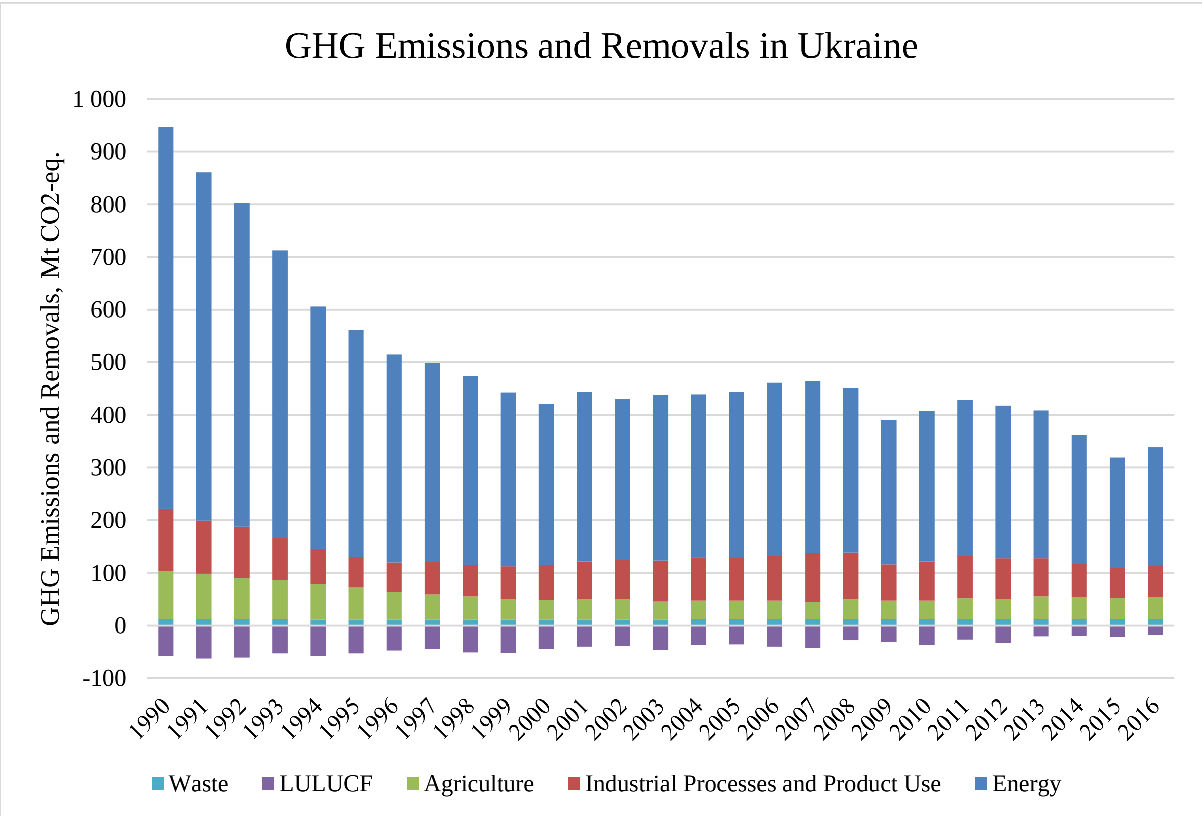

Fig. 2.7. GHG emissions and removals by sector in Ukraine, 1990-2016, Mt CO_2-eq.

Table 2.2. Greenhouse gas emissions in Ukraine by sector for the period of 1990-2016 (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	358.4	329.8	305.5	321.9	305.1
Industrial Processes and Product Use	118.0	101.1	97.2	79.2	67.0	58.0	56.2	61.9	59.9	62.5	67.1	71.6	74.5
Agriculture	92.0	86.3	78.3	74.6	67.3	60.4	51.7	47.3	44.0	38.7	36.5	38.2	38.4
LULUCF (removals)	-58.0	-62.6	-61.2	-53.1	-58.0	-52.8	-47.8	-44.3	-51.0	-51.8	-45.4	-40.4	-39.1
Waste	11.9	11.9	11.9	11.8	11.6	11.5	11.4	11.4	11.4	11.3	11.4	11.5	11.6
Total (without LULUCF)	947.3	860.9	803.2	712.6	605.9	561.3	514.7	498.2	473.6	442.4	420.5	443.3	429.6
Total (with LULUCF)	889.3	798.3	742.0	659.5	547.8	508.5	466.9	453.9	422.6	390.6	375.1	402.9	390.5
Total (without LULUCF, with indirect)	947.3	860.9	803.2	712.6	605.9	561.3	514.7	498.2	473.6	442.4	420.5	443.3	429.6
Total (with LULUCF, with indirect)	889.3	798.3	742.0	659.5	547.8	508.5	466.9	453.9	422.6	390.6	375.1	402.9	390.5

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy	314.6	310.4	315.5	328.9	327.2	313.5	275.2	285.8	295.5	290.0	280.9	245.7	210.5
Industrial Processes and Product Use	78.1	81.3	80.6	85.0	92.2	88.8	68.4	74.5	80.8	77.3	72.4	61.9	56.5
Agriculture	33.7	35.4	35.3	35.2	32.5	37.1	35.2	34.6	38.9	38.0	42.4	42.1	39.8
LULUCF (removals)	-46.9	-37.5	-35.9	-40.3	-42.6	-28.3	-31.0	-37.1	-27.0	-33.4	-20.9	-20.1	-22.1
Waste	11.7	11.9	12.0	12.1	12.4	12.3	12.3	12.4	12.5	12.4	12.5	12.4	12.3
Total (without LULUCF)	438.0	439.0	443.5	461.2	464.2	451.7	391.0	407.3	427.8	417.8	408.3	362.0	319.0
Total (with LULUCF)	391.1	401.4	407.6	420.9	421.6	423.4	360.0	370.2	400.8	384.4	387.4	342.0	296.9
Total (without LULUCF, with indirect)	438.0	439.0	443.5	461.2	464.2	451.7	391.0	407.3	427.8	417.8	408.3	362.0	319.0
Total (with LULUCF, with indirect)	391.1	401.4	407.6	420.9	421.6	423.4	360.0	370.2	400.8	384.4	387.4	342.0	296.9

	2016
Energy	225.8
Industrial Processes and Product Use	58.0
Agriculture	42.4
LULUCF (removals)	-18.0
Waste	12.4
Total (without LULUCF)	338.6
Total (with LULUCF)	320.6
Total (without LULUCF, with indirect)	338.6
Total (with LULUCF, with indirect)	320.6

The largest contribution to GHG emissions has the Energy sector. Its share in the total emissions for the period of 1990-2016 fluctuated within the range of 70.4-84.8 % with the LULUCF sector, and of 66.0-76.8 % without the LULUCF sector. Decline of emissions in the sector in 2016 compared to 1990 is 68.9% - from 725.32 to 225.79 Mt CO_2-eq. Compared to 2015 GHG emissions has increased by 7.3 %.

The largest source of GHG emissions in the Energy sector is thermal power plants (TPPs), which accounted for 37.1-45.6 % 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 10.5 % to 15.4 % from Energy sector during the whole time series and started to decrease rapidly starting from 2013. The share of GHG emissions in the category 1.A.4 “Other Sectors” in 1990-2016 was 11.7-15.4%. 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 2014-2016, 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 17.6-29.2 %, 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 1990-2015 ranged from 11.4 % to 21.9 % of the total national GHG emissions, including LULUCF (or 10.3 - 19.9 % excluding LULUCF). Total GHG emissions in the sector decreased from 101.08 Mt CO_2-eq. in 1990 to 58.04 Mt CO_2-eq. in 2016, i.e. by 50.8 %.

The largest source of carbon dioxide emissions in this sector is iron, steel, ammonia 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 2009-2016. The increase in total emissions in 2016 compared to 2015 is due to the restoration of the Ukrainian economy after the previous economic recession that began in 2014.

The share of Agriculture sector in the total volume of emissions during 1990-2016 varied in the range from 7.7 % to 13.4 % (or 7.0 - 12.5 % excluding LULUCF). The emissions fluctuation in the sector is related to a change in the number of livestock animals and their herd structure; consumption of feed and diets; 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, CO_2 removals exceeds GHG emissions, i.e. there is net GHG removals (Fig. 2.7 shows that with negative values). The value of reductions related to the total emissions in the sector reaches 10.7 % in 1999. In 2016 GHG removals are equal to 5.3 % of total emissions in Ukraine.

In 2016 net GHG removals is 18,00 Mt CO_2-eq., what is 69.0 % lower, than the reductions in 1990 (62.60 Mt CO_2-eq.). Such dynamic is related to first of all GHG emissions dynamic from mineral soils in Cropland category (in 2016 in the category 47.25 Mt CO_2-eq. emissions took place, what is 51.89 Mt CO_2-eq. more, than the level of 1990, when 4.6 Mt CO_2-eq. GHG removals occurred), what is connected with larger volumes of agricultural crop production and low level of fertilizers applied, especially organic, in recent 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 2016 the decline in peat production and peat areas reduced the emissions down to the level of 0.16 Mt CO_2-eq.

The share of Waste sector is small, but it has a fairly stable trend. From 1990 to 2016, emissions in this sector has slightly raised. Compared to the base year, they increased by 3.7 %, from 11.92 to 12.37 Mt CO_2-eq. that is caused be the sharp increase of activity on MSW disposal during 1998-2013 along with a slow pace of its biodegradable part decomposition.

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, greenhouse gas emissions amounted to 225.79 million t of CO_2-eq. or approximately 66.7 % of all GHG emissions in Ukraine (excluding sinks in the "LULUCF" sector), and decreased by 68.9 % vs the baseline 1990. Compared with 2015, emissions in the sector increased by 7.3 %.

Fig. 3.1 shows changes in direct action greenhouse gas 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 81.65 %, 17.64 %, and 0.7 %, while in 2016 – 79.76 %, 19.58 %, and 0.66 %, respectively.

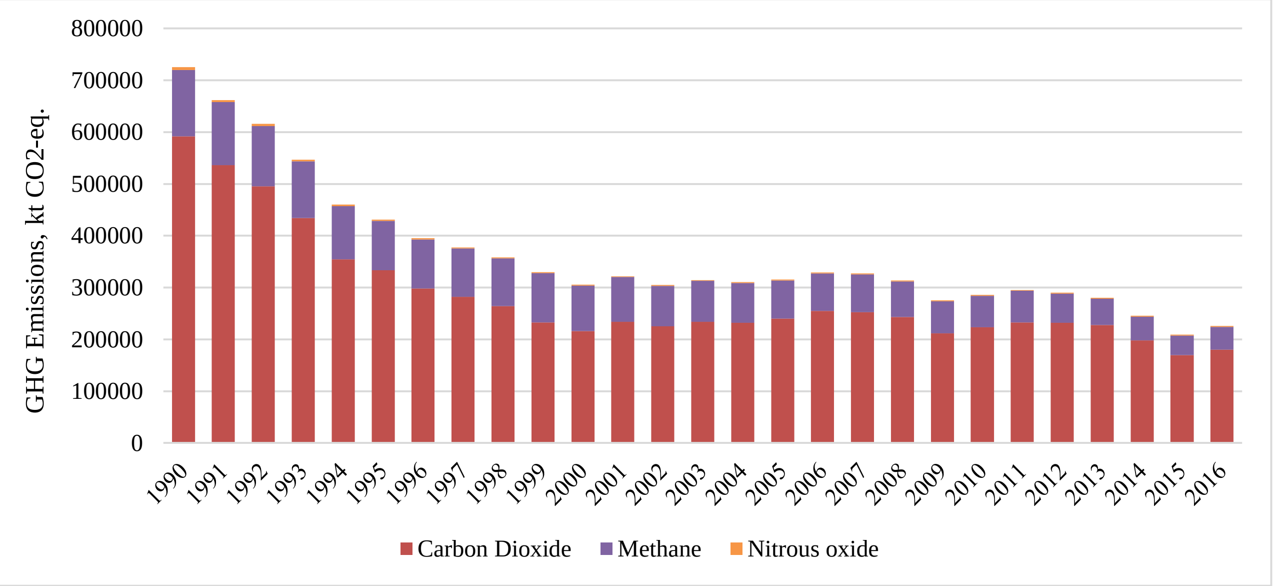

Fig. 3.1. Direct action greenhouse gas emissions in the sector "Energy", 1990-2016

In 2016, approximately 79.6 % 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" - 20.4 % (Table 3.1).

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

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
1 Energy total, including	725.27	431.35	305.44	315.48	285.73	289.92	280.42	245.59	208.93	225.79
1.A Fuel Combustion Activities	597.85	335.35	216.26	239.82	223.12	232.32	227.50	197.74	169.36	179.83
1.B Fugitive Emissions from Fuels	127.42	96.00	89.18	75.66	62.61	57.60	52.92	47.84	39.57	45.96

The dynamics of GHG emissions in the "Energy" sector in the period of 1990-2016 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 most, 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.

The ongoing military 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, and, as a consequence, to reduction in energy consumption, that led to decreasing GHG emission trend in energy sector in 2014 – 2016 in compare with 2013.

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 2016, emissions from fuel combustion amounted to 179.83 million t of CO_2-eq. and decreased as compared to 1990 by 69.9 %, while in comparison with 2015 increased by 6.2 %. More detailed information is presented in Fig. 3.2.

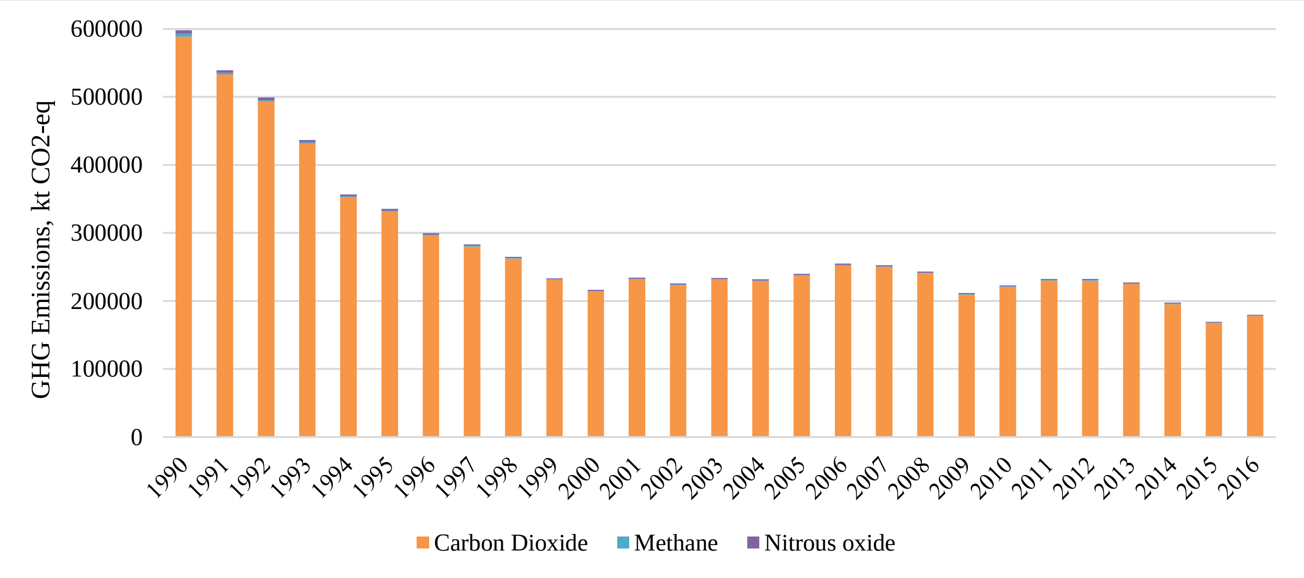

Fig. 3.2. Greenhouse gas emissions in category 1.A "Fuel Combustion Activities" (sectoral approach), 1990-2016

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 2016 – 56.42%; the share of 1.A.2 "Manufacturing Industries and Construction" was 18.6% in 1990 and 9.97% in 2016; 1.A.3 "Transport" – 18.7% and 17.9%, respectively; 1.A.4 "Other sectors" - 17.1% and 15.41%, respectively, the contribution of 1.A.5 "Unspecified Categories" was negligible until 2013, in 2016 it amounted to 0.3% (according to Table 3.2).

Table 3.2. Greenhouse gas emissions in category 1.A "Fuel Combustion Activities", mln t of CO_2-eq.

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1.A Fuel Combustion Activities total, including:	597.85	335.35	216.26	239.82	223.12	232.55	232.32	227.50	197.74	169.36	179.83
1.A.1 Energy Industries	272.68	194.73	112.77	122.36	122.30	128.99	132.20	127.94	109.80	90.67	101.46
1.A.2 Manufacturing Industries and Construction	111.26	24.99	30.50	36.51	21.97	24.54	22.35	22.35	19.53	18.76	17.93
1.A.3 Transport	111.79	49.22	34.55	39.19	40.20	40.29	39.36	39.51	35.89	31.10	32.21
1.A.4 Other sectors	102.01	66.35	38.37	41.66	38.62	38.67	38.29	37.62	32.13	28.42	27.71
1.A.5 "Unspecified categories"	0.11	0.06	0.06	0.08	0.03	0.07	0.12	0.08	0.40	0.41	0.53

Changes in the structure of emissions from fuel combustion in the period of 1990-2016 by IPCC categories are presented in the diagram (Fig. 3.3).

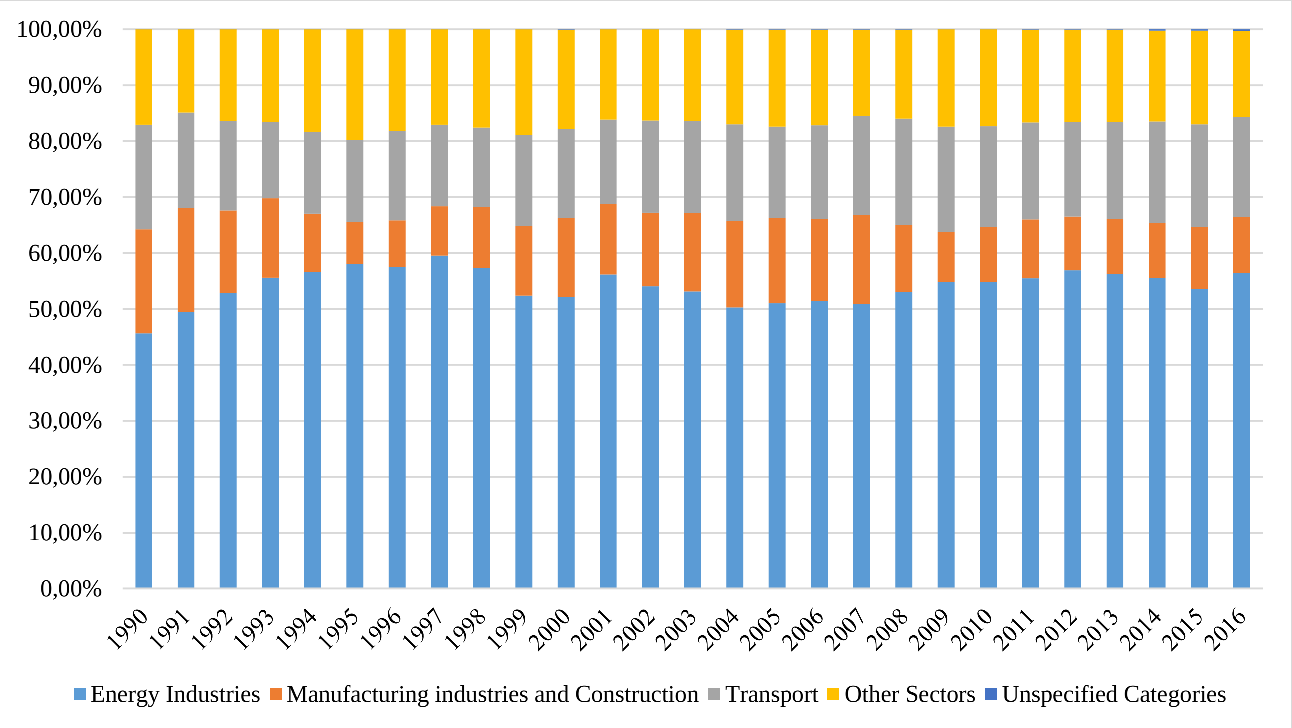

Fig. 3.3. Changes in the structure of emissions from fuel combustion by IPCC categories

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 (net calorific value) 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.

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, mln t	CO_2 emissions determined using the sectoral approach, mln t	Discrepancy between sectoral and reference approaches, %
1990	608.89	588.77	3.31
1991	607.27	533.14	12.21
1992	525.63	493.09	6.19
1993	418.70	431.68	-3.10
1994	349.85	352.27	-0.69
1995	342.88	331.26	3.39
1996	283.00	296.01	-4.60
1997	267.35	279.77	-4.64
1998	258.89	262.01	-1.20
1999	239.97	230.85	3.80
2000	229.81	213.90	6.92
2001	232.06	231.84	0.10
2002	243.29	223.27	8.23
2003	232.21	231.31	0.39
2004	242.71	229.46	5.46
2005	249.79	237.49	4.93
2006	259.67	252.35	2.82
2007	260.54	250.15	3.99
2008	245.66	240.71	2.01
2009	209.75	209.38	0.18
2010	219.17	220.74	-0.72
2011	232.55	230.11	1.05
2012	225.91	229.84	-1.74
2013	217.05	225.01	-3.67
2014	196.82	195.48	0.68
2015	176.60	167.28	5.28
2016	179.26	177.72	0.90

In 2016, the difference between CO_2 emissions calculated under the reference and sectoral approaches was 0.87 %. Certain influence on the data in 2014 - 2016 had that fact that the stock change of natural gas in the Autanomous Republic of Crimea is not available and were not considered.

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

3.2.2.1 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, while the destination airport is outside Ukraine. 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 international aviation in 2016 amounted to 998,4 kt of CO_2-eq., which is 15,4 % higher than the same indicator in 2015 and 59.5 % lower than in 1990 (see fig. 3.4).

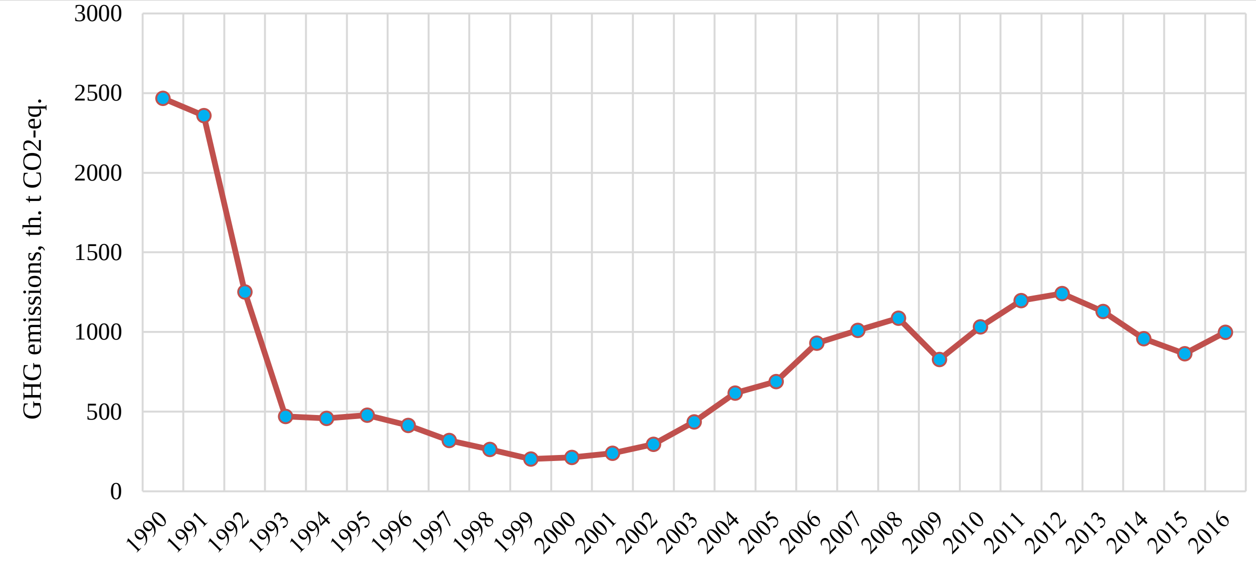

Fig. 3.4. GHG emissions from international air transport, 1990-2016

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) [30].
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), tonnes;
FC_{H50} - consumption of fuels by economic activity type (FEA) H50 "Water Transport" for transportation needs (gasoil, fuel oil), tonnes;
$K_{1.d.1.b}$ - 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, thousand tonnes.
PS_{int} is the volume of cargo transportation by international sea transport, thousand tonnes.
PR - total volume of cargo transportation by river transport, thousand tonnes.
PS - total volume of cargo transportation by sea transport, thousand tonnes.

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].

The results of estimating emissions from international water transport are presented in Table 3.4.

Table 3.4. GHG emissions from international water transport by fuels

Year	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
GHG emissions, kt of CO_2-eq.											
International waterway transport	1598.86	969.21	399.06	279.03	140.18	85.01	76.73	85.91	79.79	75.32	75.00

3.2.2.3 Category-specific recalculations

No recalculation 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 furnace). Emissions from non-energy fuel use are presented in the sector "Industrial Processes and Product Use" 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 No. 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 incineration, 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 1990-2016, 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 2016, emissions in category 1.A.1 "Energy Industries" amounted to 101.5 million t of CO_2-eq., or about 56.4 % of the total emissions in category 1.A "Fuel Combustion Activities", and decreased by 62.8 % compared with the baseline 1990 (see Table 3.5), they increased by 6.2 % compared to 2015.

Table 3.5. GHG emissions in the category "Energy Industries", Mt of CO_2-eq.

Emission category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1.A.1 Energy Industries. total	272.68	194.73	112.77	122.36	122.30	128.99	132.20	127.94	109.80	90.67	101.46
1.A.1.a Electricity and Heat Production	255.52	187.77	105.38	110.40	110.51	117.14	121.99	118.11	102.41	85.23	95.87
1.A.1.b Petroleum Refinery	6.36	1.88	1.40	1.23	0.87	0.89	0.57	0.65	0.35	0.30	0.29
1.A.1.c Solid Fuel Production and Other Energy Industries	10.79	5.08	6.00	10.73	10.92	10.95	9.65	9.18	7.04	5.14	5.3

3.2.7.1.1 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 thermal power plants (TPP), combined heat and power plants (CHP), boiler rooms (heating plants – HP), heat power plants of enterprises, 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 2016 amounted to 95.87 mln. t of CO_2-eq., having increased with respect to 2015 by 12.5%, and decreased by 62.5% compared with the baseline 1990. Since acceleration of electricity production volumes occurred mainly due to the higher load on capacity of large TPPs, which are the key consumers of coal in the country, the share of this type of fuel in the balance increased. Another factor influencing the structure of fuels consumed in the category is reduction of natural gas consumption and its corresponding replacement with coal after 2006.

The increase in the balance of the share of liquid fuel in 2009 compared to 2008 was due to increased consumption of fuel oil by power plants and boiler houses. The technical possibility of replacing natural gas with fuel oil is defined by the fact that oil-gas boilers are installed at power plants, where fuel oil can be used as a backup and emergency fuel.

GHG emissions in category 1.A.1.a by fuels groups is presented in fig. 3.5.

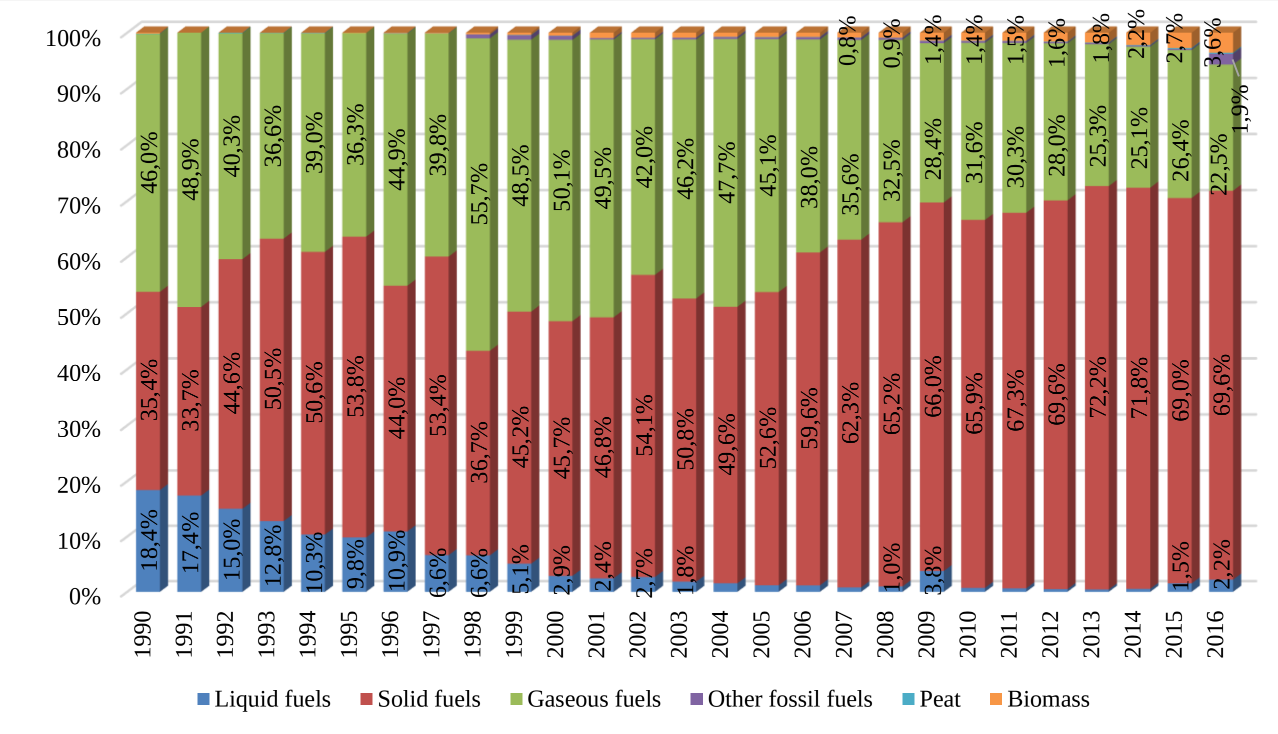

Fig. 3.5. GHG emissions in category 1.A.1.a by fuel groups, % of the category

The structure of GHG emissions in the category 1.A.1.a "Electricity and Heat Production" by energy facilities for 1998-2016 is presented in fig. 3.6.

For the whole period 1998-2016, the largest share of GHG emissions in the category corresponds to TPPs – from 40.5 % to 67.5 %, for the rest: CHPs – from 12.9 % to 22.4 %, HPs – from 18.7 % to 46.8 %.

In 2016 GHG emissions from TPPs were equal to 60.5 mln. t of CO_2-eq., having increased with respect to 2015 by 10.2% and 5.9 % lower than in 1998.

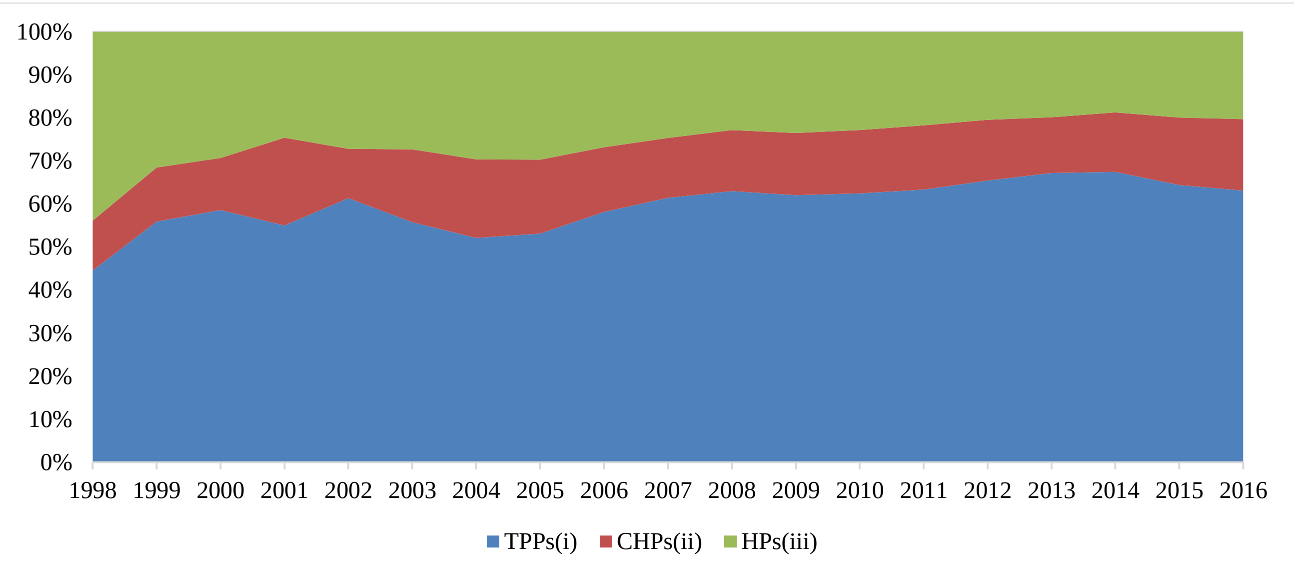

Fig. 3.6. The structure of GHG emissions in the category 1.A.1.a "Electricity and Heat Production" by energy facilities, 1998-2016

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 decreased by 2.9 % in 2016 compared to 2015 and amounted to 0.29 mln. t of CO_2-eq., which is due to a reduction in production of refined petroleum products in 2016. Compared to 1990, GHG emissions reduced 21.9 times.

3.2.7.1.3 Solid Fuels Production 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 2016 amounted to 5.3 mln t of CO_2-eq, which is 3.11 % higher than the same indicator in 2015 and 50.9 % 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 2016 – in section A2.9 . National circumstances for 2014 - 2016 are provided in Annex A2.10.

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 in 2017 [21] according to which the country-specific NCV, oxidation factor and carbon content as well as mass combusted were determined for the period 1990-2016 (Annex A2.6.2).

Other fuels consumed in subcategories "Electricity Production" (i), "Combined Heat and Power Production" (ii), and "Thermal 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 Production" (i), "Combined Heat and Power Production" (ii), and "Thermal 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 Refinery (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: crude oil, natural gas, refinery feedstock and fuel oils.

The data on energy use of fuel in this sub-category are based on the total fuel consumption for oil refining by fuels under form No.11-MTP (fuel).

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.

3.2.7.2.3 Solid Fuels Production and Other Industries (CRF category 1.A.1.c)

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

The data on energy use of fuels in this sub-category - see Annex A2.4.

Estimation of CO_2 emissions from combustion of natural gas, gasoline, diesel, LPG and coal coke 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 detailed shown in chapter 3.3.1.2.1 "Underground mines" below.

3.2.7.3 Uncertainties and time series-consistency

Uncertainties of activity data and emission factors are present in Table 3.6.

Table 3.6. 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	1.50	2	150	500
Solid fuel	1.67	5	150	500
Gaseous fuel	3.65	5	150	500
Other types of fuels	31.14	5	150	500
Biomass	30.23	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 4.32 %.

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 2003-2016 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 State Statistics Service 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).

3.2.7.5 Category-specific recalculations

No recalculation were performed in the category.

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 2016, emissions in category 1.A.2 "Manufacturing Industries and Construction" amounted to 17.93 th. t of CO_2-eq., or about 9.9 % of the total emissions in category 1.A "Fuel Combustion", and decreased by 83.9% compared with 1990 (see Table 3.7). Compared with 2015, emissions decreased by 4.4%.

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	2011	2012	2014	2015	2016
1.A.2 Manufacturing Industries and Construction in total, including:	111.26	24.99	30.50	36.51	21.97	24.54	22.35	19.53	18.76	17.93
1.A.2.a Iron and Steel	55.35	15.39	24.44	24.17	12.71	13.96	13.11	11.50	11.46	9.93
1.A.2.b Non-Ferrous Metals	0.65	0.61	0.46	0.66	0.58	0.56	0.35	0.82	0.82	0.75
1.A.2.c Chemicals	3.52	1.57	0.77	1.09	0.80	1.02	0.98	0.45	0.41	0.53
1.A.2.d Pulp, Paper and Print	0.14	0.20	0.01	0.05	0.04	0.04	0.05	0.01	0.03	0.04
1.A.2.e Food Processing, Beverages. and Tobacco	3.64	2.42	0.87	0.81	0.56	0.65	0.62	0.51	0.42	0.54
1.A.2.f Non-Metal Minerals	16.10	2.61	2.38	5.80	4.29	5.06	4.07	3.48	3.40	3.59
1.A.2.g Other Industries	31.85	2.20	1.57	3.94	2.98	3.25	3.17	2.76	2.21	2.54

Changes in the structure of emissions from fuel combustion in the period of 1990-2016 by category 1.A.2 are presented in the diagram (Fig. 3.7).

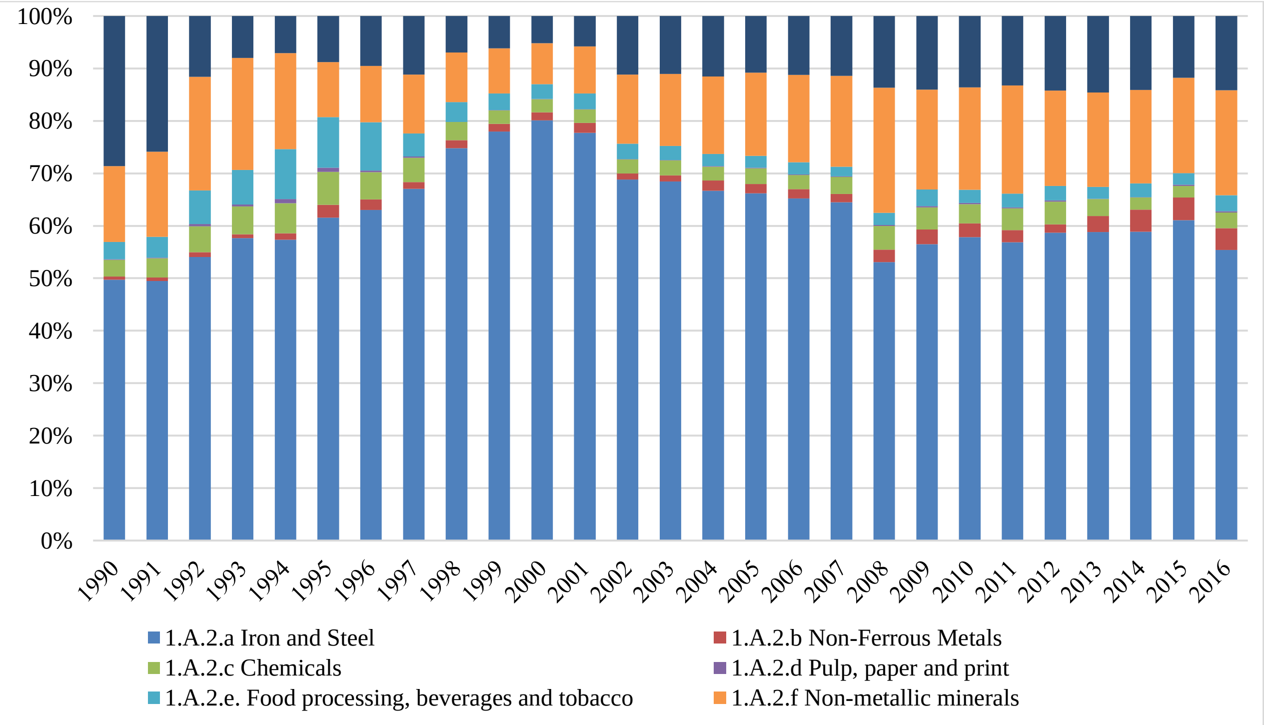

Fig. 3.7. Changes in the structure of emissions from fuel combustion in category 1.A.2 "Manufacturing Industries and Construction", %

Emissions that result from use of fossil fuels or their processing products as raw materials or chemical reagents are recorded in CRF sector 2 "Industrial Processes and Product Use". 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 [12, 13] 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].

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

In 2016, the country produced 24.2 million tonnes of steel, which is 5.2 % more than in the previous 2015.

In 2016, GHG emissions in this category amounted to 9.93 million tonnes of CO_2-eq, which is 13.3% lower than the same indicator in 2015 and 82.1% lower than in 1990. But when comparing the values of consumption in energy units (TJ) there is observed increasing in 2016 relatively 2015 by 0.68%. This is due to a redistribution between the consumption of coal and coke oven gas in this category. Coke used for recovery of iron ore is accounted for in IPPU according to [1].

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 2016, GHG emissions in this category amounted to 0.75 mln t of CO_2-eq., which is 8.95% lower than in 2015 and 13.96 % 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 prodaction of ammonia is accounted for in IPPU according to [1].

In 2016, GHG emissions in this category amounted to 0.53 mln. tonnes of CO_2-eq., which is 31.5 % higher than the same indicator in 2015 and 6.6 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 2016, GHG emissions in this category amounted to 44.6 th. tonnes of CO_2-eq., which is 2.9 % higher than the same indicator in 2015 and 68.5 % lower than in 1990.

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

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

In 2016, GHG emissions in this category amounted to 0.54 mln. tonnes of CO_2-eq., which is 27.6 % higher than the same indicator in 2015 and 6.7 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 industrial products by companies in the construction industry, as well as production of construction materials and non-fuel non-metal raw material mining.

In 2016, GHG emissions in this category amounted to 3.59 mln. tonnes of CO_2-eq., which is 5.5% higher than the same indicator in 2015 and 4.5 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.A2.a-1.A.2.f, namely: construction, machinery, wood products, furniture, electronics, textiles, and so on.

In 2016, GHG emissions in this category amounted to 2.54 mln. tonnes of CO_2-eq., which is 14.7% higher than the same indicator in 2015 and 12.6 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 were based on statistical data on consumption of fuels presented in the statistical reporting form "4-MTP". National circumstances for 2014, 2015 and 2016 are provided in Annex A2.10.

3.2.8.3 Uncertainties and time series-consistency

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

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

Type of fuel	Uncertainty of activity data, %	Uncertainities of emissions factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	4.6	1	150	500
Solid fuel	4.76	5	150	500
Gaseous fuel	4.62	5	150	500
Other types of fuels	20.1	5	150	500
Biomass	20.02	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 6.04%.

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 State Statistics Service of Ukraine.

3.2.8.5 Category-specific recalculations

No recalculation were performed in the category.

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 2016, emissions in category 1.A.3 "Transport" amounted to 32.21 mln. tonnes of CO_2-eq. Compared to 1990, emissions decreased by 71.5%, to the previous 2015 - increased by 3.5%.

The largest contribution into GHG emissions in category 1.A.3 "Transport" in 2016 was made by emissions in categories 1.A.3.b "Road Transport" and 1.A.3.e "Other Types of Transportation" – 71.4 % and 25.5 %, respectively (see. Table 3.9).

Table 3.9. GHG emissions in category 1.A.3 "Transport", mln. tonnes of CO_2-eq.

Emission category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1.A.3 Transport total, including:	111.8	49.2	34.6	39.2	40.2	40.3	39.4	39.5	35.9	31.1	32.2
1.A.3.a Civil Aviation	0.7	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
1.A.3.b Road Transport	61.4	20.7	15.8	22.2	28.9	28.4	29.1	28.9	26.7	22.8	23.3
1.A.3.c Railways	3.8	1.3	1.4	0.9	0.5	0.5	0.4	0.4	0.5	0.4	0.5
1.A.3.d Waterway Transport	3.3	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1.A.3.e Other types of transport	42.6	26.6	17.1	15.7	10.5	11.1	9.6	10.0	8.6	7.7	8.2

Changes in the structure of emissions from fuel combustion in the period of 1990-2016 by category 1.A.3 are presented in the diagram (Fig. 3.8).

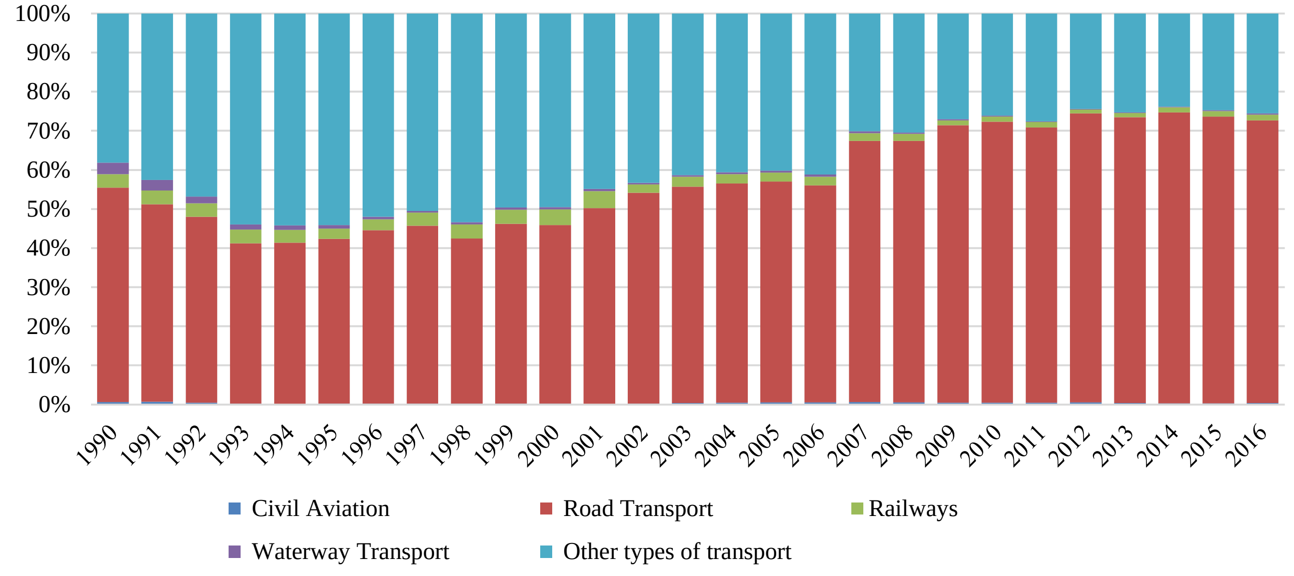

Fig. 3.8. Changes in the structure of emissions from fuel combustion in category 1.A.3 "Transport", %

3.2.9.2 Methodological issues

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 fuel 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 2016 amounted to 131.1 th. tonnes of CO_2-eq. which is 57.8% higher than the same indicator in 2015 and 80.8 % lower than in 1990. For details on GHG emissions from domestic aviation, see Fig. 3.9.

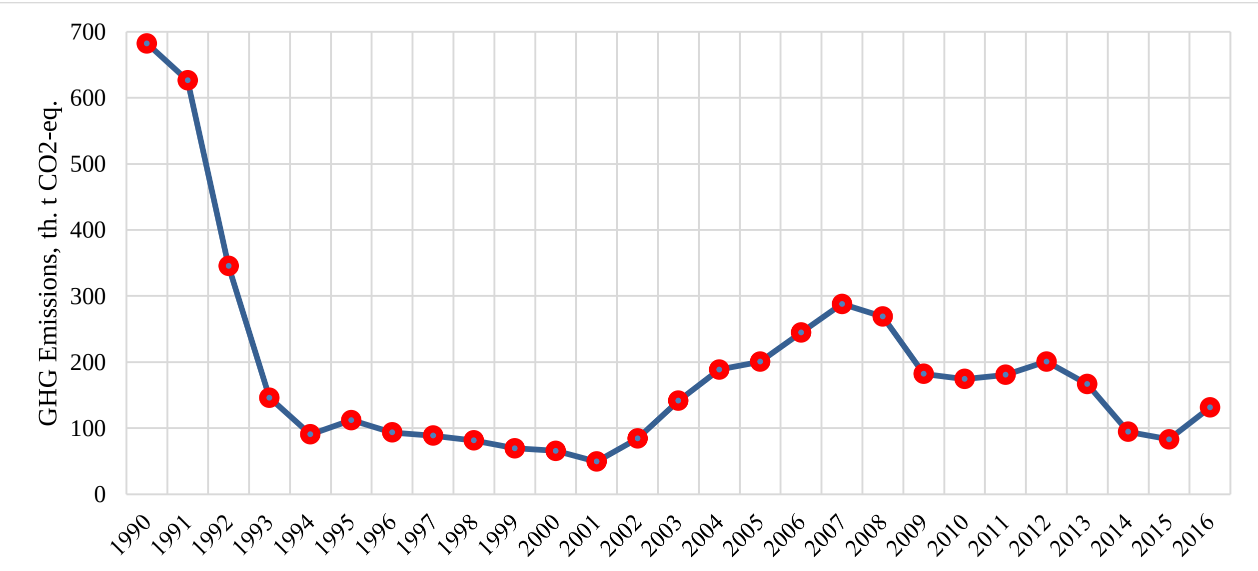

Fig. 3.9. GHG emissions from domestic aviation, 1990-2016

GHG emission trends for domestic air transport in general correspond to those of international aviation (see sub-section 3.2.2.1).

Estimation of CO2 emissions from aviation kerosene was held under the method corresponding to Tier 3, for CH_4 and N_2O – Tier 2, in accordance with [1], for aviation gasoline– to Tier 1.

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 by vehicles owned by individuals.

In category 1.A.3.b "Road Transport", GHG emissions in 2016 amounted to 23.3 mln. tonnes of CO_2-eq., having increased with respect to 2015 by 2.1 %, and decreased by 62.1 % compared with 1990. GHG emissions, as well as their structure by fuels used, in accordance with the national energy statistics are presented in Fig. 3.10.a and 3.10.b.

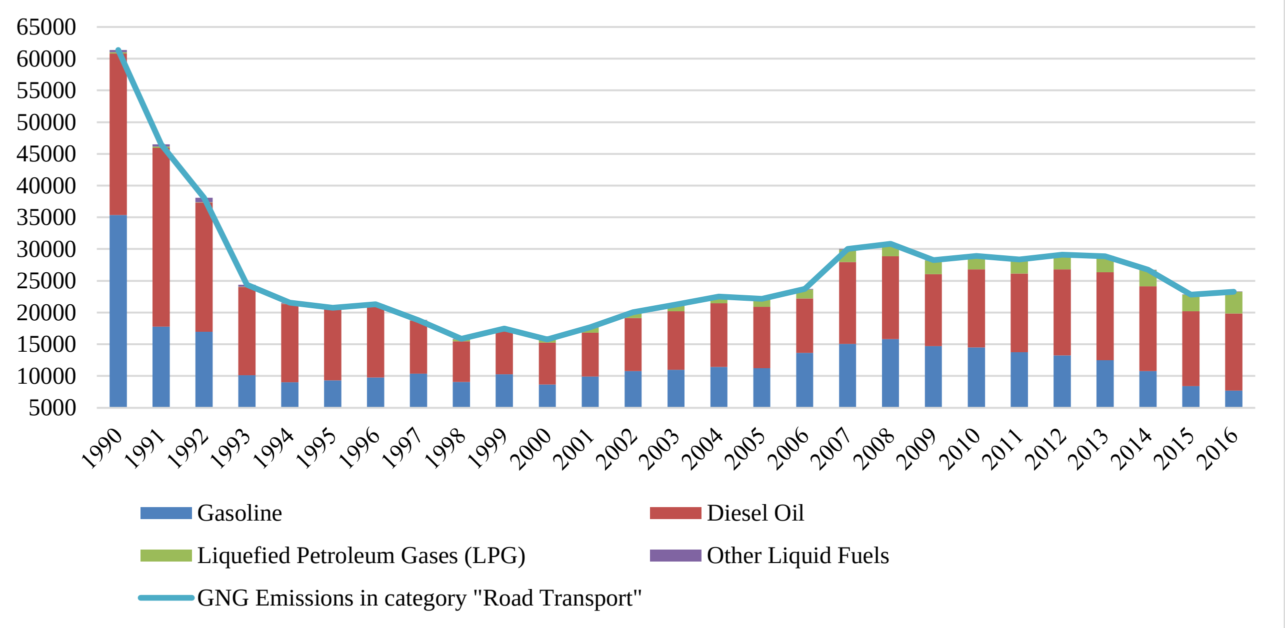

Fig. 3.10.a. GHG emissions in category 1.A.3.b "Road Transport" by fuels, for 1990-2016, in kt of CO_2-eq

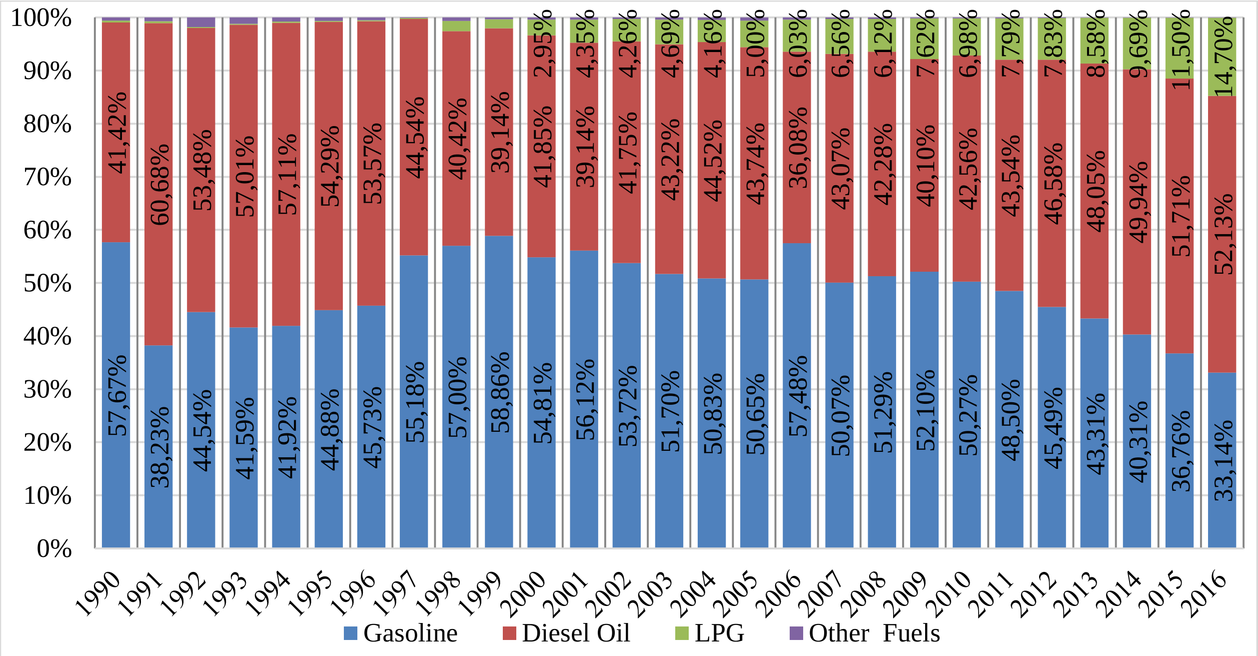

Fig. 3.10.b. GHG emission structure in category 1.A.3.b "Road Transport" by fuels, for 1990-2016, in %

The structure of GHG emissions in the category "Road Transport" by fuels gradually changed over the period of 1990-2016. Thus, in the period of 1991-1999 the share of emissions from combustion of motor gasoline increased gradually, namely - from 38.2 % to 58.9 %, respectively, and, on the other hand, during this period the share of gas oils was reduced from 60.7 % to 39.1 %.

Emissions in the category for the entire time series of 1990-2016 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 [3-10, 29,30] taking into account the analytical study [26] 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.

This approach to GHG inventory in this category is due to the fact that national energy statistics are 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 were calculated by surrogate method on the basis of 2015 taking into account that consumption of gasoline decreased by 8%, diesel fuel increased by 2%, LPG - increased by 30%, according to expert estimation.

National circumstances for 2014 - 2016 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 2016, emissions in the category amounted to 0.47 mln. tonnes of CO_2-eq., having increased with respect to 2015 by 4.5 %, and to the baseline 1990 – decreased by 8.1 times.

Emissions in this category were evaluated using the procedure described in Annex 2.4.2. 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 - 2016 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 H 50 "Waterway Transport" in accordance with the FEA [15].

GHG emissions from bunker fuels used for sea transport are not included in the total emissions but are shown in the CFA separately as reference data.

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

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

where $FC_{1.A.3.d}$ is consumption of fuels by domestic waterway transport (gasoil, fuel oil), tonnes;
FC_{H50} - consumption of fuels by economic activity type (FEA) H50 "Water Transport" for transportation needs (gasoil, fuel oil), tonnes;
$k_{1.A.3.d}$ - the factor of fuel distribution into coastal transportation, in relative terms, which is defined by the following expression:

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

where PR_h is the volume of cargo transportation by domestic river transport, thousand tonnes;

PSh is the volume of cargo transportation by domestic sea transport, thousand tonnes;
PR - total volume of cargo transportation by river transport, thousand tonnes;
PS - total volume of cargo transportation by sea transport, thousand tonnes.

In 2016, emissions in the category amounted to 82,6 th. tonees of CO_2-eq., having increased with respect to 2015 by 8.2 %, and to the baseline 1990 - having decreased 39.5 times. For the same reason as for the railroad transport, in 2009 there was a substantial reduction in emissions in the category - by 41.1% compared to the same indicator for 2008. The method used for estimating the emissions corresponds to Tier 2 for CO_2 emissions from diesel combustion and Tier 1 – for heavy oil and non-CO_2 gases in accordance with [1].

National circumstances for 2014 - 2016 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 fuel gas was determined according to data of the State Company "Ukrtransgaz" NJSC "Naftogaz", which is the national operator of the gas transportation system of Ukraine.

In 2016, emissions in the sub-category amounted to 2.7 mln. tonnes of CO_2-eq., having increased with respect to 2015 by 24.1 %, and to the baseline 1990 – decreased by 70.9%.

Emission factors of non-CO_2 gases were considered the same as in category 1.A.1.a "Electricity and Heat Production", as gas turbines used in gas pipelines by their technical characteristics are close to power units.

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 2016, emissions in the sub-category amounted to 5.5 mln. tonnes of CO_2-eq., having increased with respect to 2015 by 0.6 %, and to the baseline 1990 - decreased in 6 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 fuel volumes were calculated by surrogate method on the basis of 2015 taking into account that consumption of gasoline decreased by 8%, diesel fuel increased by 2%, LPG - increased by 30%.

National circumstances for 2014 - 2016 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 3.10.

Table 3.10. Uncertainties of activity data and emission factors in category 1.A.3 "Transport"

Uncertainty of activity data, %	**Uncertainties of emissions factors, %**		
	CO_2	**CH_4**	**N_2O**
10.33	4.57	15.39	10.94

Estimated total GHG emission uncertainty in this category is 10.89 %.

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". When estimating the amounts of fuel used by road transport, alternative sourses of data were taken into account, including information from expert opinions and publications.

3.2.9.4 Category-specific QA/QC procedures

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

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

3.2.9.5 Category-specific recalculations

No recalculation were performed in the category.

3.2.9.6 Category-specific planned improvements

To carry out verification of motor fuels consumption in different categories and in transport sector in total for 1990-2016.

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

3.2.10.1 Category description

In 2016, GHG emissions in category 1.A.4 "Other Sectors" amounted to 27.71 mln. tonnes of CO_2-eq., and decreased as compared to 2015 by 2.5 %, while in comparison with the baseline 1990 – by 72.8 %.

The key source of emissions in 2016 is sub-category 1.A.4.b "Residential Sector", which accounted for approximately 91.7% of the total emissions (see Table 3.11).

Table 3.11. GHG emissions in category 1.A.4 "Other Sectors", Mt of CO_2-eq.

Emission category	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
1.A.4 Other Sectors total, including	102.01	66.35	38.37	41.66	38.62	38.67	38.29	37.62	32.13	28.42	27.71
1.A.4.a Commercial/Institutional Sector	38.73	23.83	6.06	4.54	2.68	2.76	2.55	2.00	1.64	1.55	1.89
1.A.4.b Residential Sector	59.46	41.53	32.15	36.94	35.73	35.56	35.37	35.10	30.20	26.58	25.41
1.A.4.c Agriculture/Forestry/Fishery/Fishing	3.82	0.99	0.16	0.18	0.21	0.35	0.37	0.52	0.29	0.29	0.41

Changes in the structure of emissions from fuel combustion in the period of 1990-2016 by category 1.A.4 are presented in the diagram (Fig. 3.11).

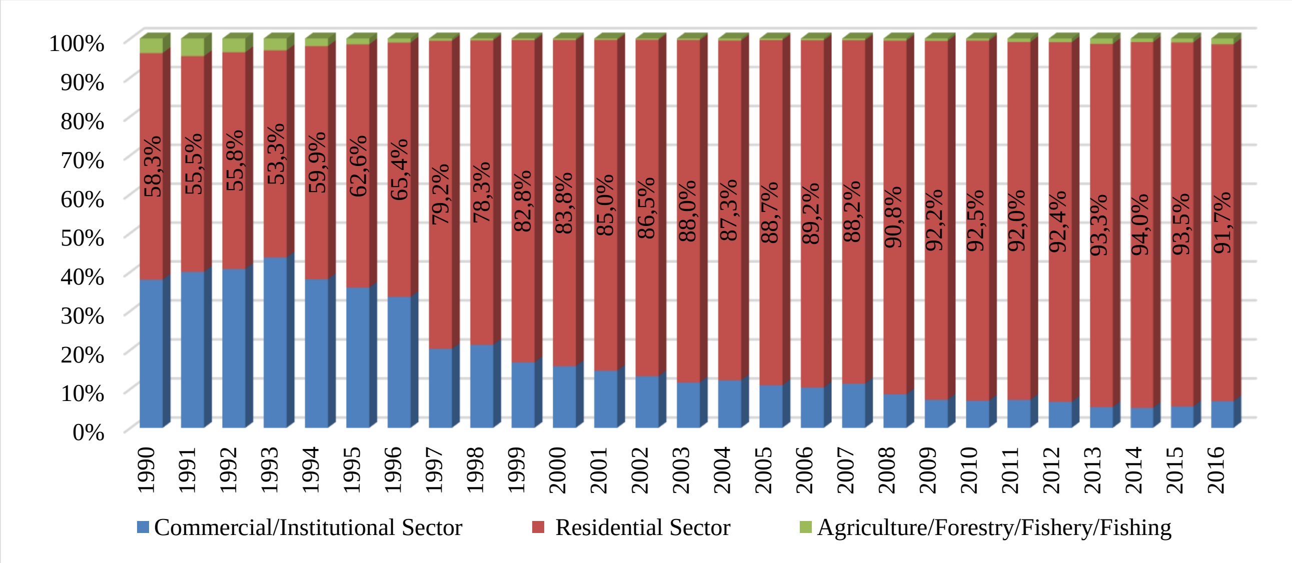

Fig. 3.11 Changes in the structure of emissions from fuel combustion in category 1.A.4 "Other Sectors", %

Emissions in category 1.A.4 "Other Sectors" are mainly due to heating of premises and water heating.

A characteristic feature of category 1.A.4.b "Residential Sector" is replacement of solid fuels with natural gas.

While in 1990 the residential sector consumed 16.3 million tonnes of coal, coal and peat briquettes [2] (see Fig. 3.12), in 2016 - only 0.78 million tonnes of the same types of solid fuel. At the same time, natural gas consumption in the years 1991-2013 in the category increased significantly - from 9.0 billion m3 in 1990 [2] to 17.2 billion m3 in 2013, while in 2016 it reduced to 12.3 billion m3.

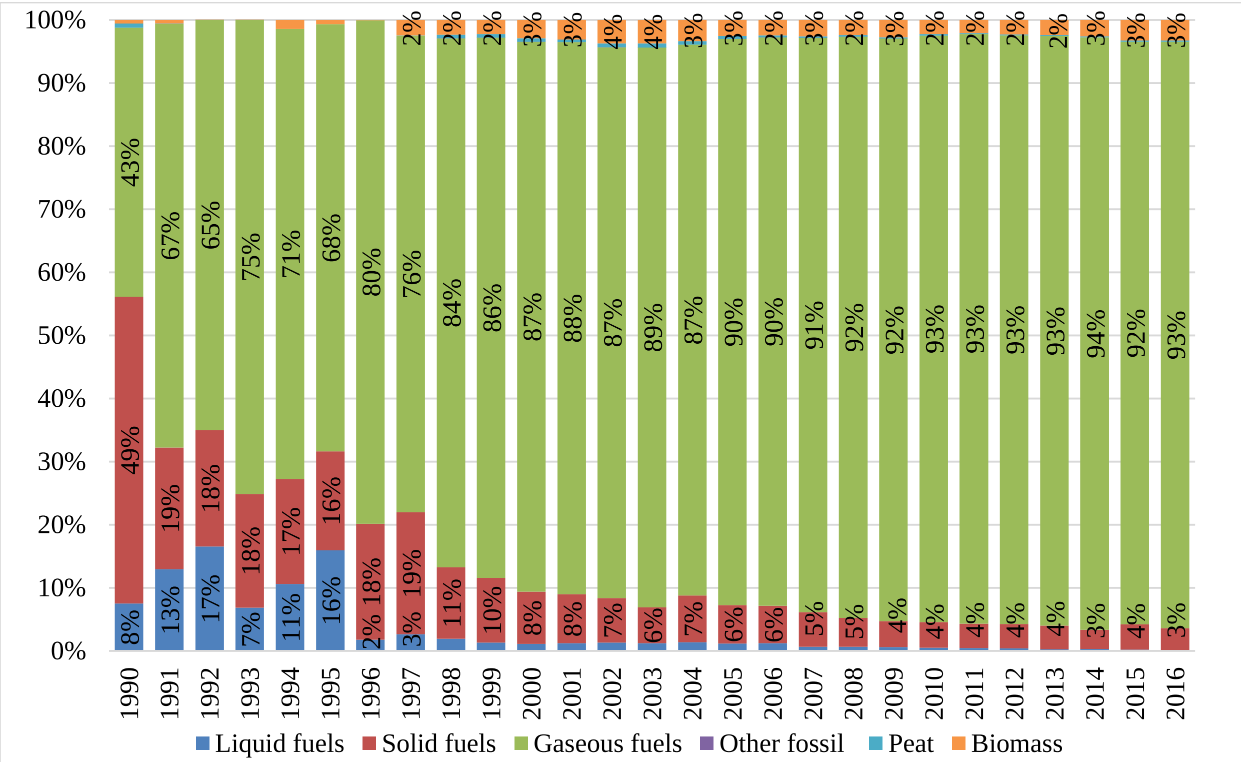

Fig. 3.12. Changes in the structure of fuel consumption in category 1.A.4.b "Residential Sector", 1990-2016.

3.2.10.2 Methodological issues

Emissions related to fuel combustion were evaluated using the procedure described in Annex 2. National circumstances for 2014 - 2016 are provided in Annex A2.10.

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

Uncertainities of activity data and emission factors are present in Table 3.12.

Table 3.12. 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	8.12	2	150	500
Solid fuel	14.82	5	150	500
Gaseous fuel	7.05	5	150	500
Other types of fuels	20.00	5	150	500
Biomass	20.26	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 9.69 %.

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 State Statistics Committee of Ukraine was established, and analysis of forms of statistical reporting containing the original data for GHG emission calculation was conducted together with the Committee's specialists.

3.2.10.5 Category-specific recalculations

No recalculation were performed in the category.

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 2016, GHG emissions in category 1.A.5 "Unspecified Categories" amounted to 0.53 mln. tonnes of CO_2-eq., which is 30.5 % higher than in 2015 and to the baseline 1990 – increased by 5 times (Table 3.13).

Table 3.13. Greenhouse gas emissions in the category "Unspecified Categories", ths. tonnes of CO_2-eq.

Category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1.A.5	105.93	57.27	59.00	84.44	31.60	66.21	119.24	78.01	397.74	405.88	529.75

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 motor 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 3.14.

Table 3.14. Uncertainties of activity data and emission factors in category 1.A.5 "Unspecifield Categories"

Type of fuel	Uncertainty of activity data, %	Uncertainties of emissions factors, %		
		CO_2	CH_4	N_2O
Liquid fuel	5.00	2	150	500

Estimated total GHG emission uncertainty in this category is 5.51 %.

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 recalculation 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 combustion of hydrocarbons except when recovered methane is utilized as an energy source that are included into CRF category 1.A.1.c.i Manufacture of solid fuels.

In 2016 emissions in category 1.B Fugitive Emissions from Fuels accounted for 45.96 Mt of CO_2-eq. or about 20.3% of the total emissions in the Energy sector, and decreased by 64.2% compared to 1990. From 2015, emissions in this category have increased by 11.7%.

In 2016, 36.1% of emissions in the category 1.B Fugitive Emissions from Fuels were in the category "Solid Fuels", and 63.9% - in the category Oil and Natural Gas (see Table 3.15).

Table 3.15 . Emissions in category 1.B Fugitive Emissions from Fuels, Mt CO_2-eq.

Emission category	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1.B Fugitive Emissions from Fuels (total), including:	127.42	96.00	89.18	75.66	62.61	62.89	57.60	52.92	47.84	41.1	45.96
1.B.1 Solid Fuels	62.33	38.23	32.92	25.90	23.66	23.64	23.96	23.38	18.62	14.36	16.6
1.B.2 Oil and Natural Gas	65.09	57.77	56.26	49.76	38.95	39.25	33.64	29.54	29.22	26.7	29.3

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 Makeyevka State Scientific and Research Institute for Safety in Mines (MakNII) 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].

In 2016, the amount of methane emissions from underground coal mines amounted to 653.5 thousand tons with a capacity of 60.18 million tons of untreated coal. Since 1990 methane and raw coal production from coal mines decreased by 73.5% and 61.3%, respectively.

1.b.1.a.1.i Mining activities. This category included methane emissions from mining activities and coal bed methane that was flared. The recovered methane utilized as an energy source accounted into CRF category 1.A.1.c Solid Fuels Production and Other Energy Sectors.

The volume of coal bed methane (include recovery and flaring) from 1990 to 2000 are taken from [17]. For 2003 - 2012 information is taken from scientific research work [11] and shown in table 3.23, for 2001 and 2002 - interpolation based on 2000 and 2003 and data on coal production. For calculation of emissions from flaring of drained methane default method and EFs were used, which are provided in [1]. For calculation of emissions from 2013 to 2016 the surrogate data method was used based on 2012 and data on coal production for 2013 – 2016.

The data about coal bed methane that was flared was taken from scientific research work [11] and shown in table 3.16. Until 2005, this activity has not occurred.

In 2016, methane emissions from mining activities amounted to 578.43 kt and compared to 1990 they decreased by 74.3%, and increased by 15.6% – to 2015.

For 2014, the activity data about raw coal production in accordance with the statistical form 1-P and the analytical study [26] and for 2016 – in line with methodology aspects for 2014.

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 3.16 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 [16], the coefficient accounting for the degree of degassing of chipped coal during the transportation time is determined by the formula:

$$k = a \cdot T^{в}, \qquad (3.5)$$

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 [11].

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, m^3/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 [17]. The general methane emission factor obtained as a result for all Ukrainian mines was 2.4 m^3/t. Therefore, for estimation of methane emissions after coal mining at gas mines the emission factor of 2.4 m^3/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 [11].

In 2016, post-mining methane emissions amounted to 72.3 kt and compared to 1990 they decreased by 66.1%, and increased by 15.7% – to 2015.

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. Therefore, 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 vacuum pump plants (VPP) on the surface. For each gas mine, the data were taken from the orders establishing methane-based mine categories. The orders contains 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 2013-2016 the surrogate data method based on 2012 information was used. The amount of GHG emissions was evaluated being inversely to coal mined in 2013 - 2016 respectively.

Methane emissions from abandoned undergrounds mines in 2016 amounted to 2.81 kt, which is 53.2 % lower than the same indicator in 1990 and 13.5% - to 2015.

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).

In 2016, methane emissions from surface coal mining totaled to 9.8 tons that 1.1% lower than in 2015.

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 2016 the surrogate data method was used based on 2013 and data on coke production for 2015 – 2016.

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

Carbon dioxide emissions associated with loss of coke oven gas in production of coke in 2016 amounted to 225.5 thousand tons, which is 45.7% lower than in 1990 and 9.5% higher than in 2015.

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

This category includes CO_2 emissions associated with coal bed methane flaring. Table 3.16 provides detailed information on methane flaring in Ukraine during 1990-2015. The surrogate data method was used based on 2012. GHG emissions were estimated according to equation 1.4.5 [1], on

Table 3.16. The amount of coal mine methane utilization in Ukraine, 2003-2012.

#	Mine	Amount of utilized methane, thousand m³/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 m³	25333	40263	54101	82887	120214	99225	119209	143044	149018.43	145825.24	

the basis of activity data indicated in the table 3.16. In 2016 emissions in the sub-category amounted to 50.7 thd. tonnes of CO_2-eq. and having increased with respect to 2015 by 15.6 %.

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 vacuum pumping plants, 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 not more than 10.5 %. Uncertainty of carbon dioxide emissions is estimated as 7.1%.

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.

3.3.1.5 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.

3.3.1.6 Category-specific recalculations

Recalculations in the category 1.B.1c "Solid fuel, other, flaring" were carried out due to the error in previous inventories as to calculation of coal bed methane flaring. The results of the revision of emissions in category 1.B.1 are indicated in the tables 3.17, 3.18.

Table 3.17. Results of the revision of emission in category 1.B.1.c

Year	Inventory Report, 2017 submission			Inventory Report, 2018 submission		
	Activity Data, Mt	Emissions, kt		Activity Data, Mt	Emissions, kt	
		CH_4	CO_2		CH_4	CO_2
1990	NA	NA	NA	0.0162	43.76	0.32
1991	NA	NA	NA	0.0139	37.70	0.28
1992	NA	NA	NA	0.0141	37.92	0.28
1993	NA	NA	NA	0.0124	33.47	0.25
1994	NA	NA	NA	0.0082	22.16	0.16
1995	NA	NA	NA	0.0083	22.34	0.17
1996	NA	NA	NA	0.0083	22.38	0.17
1997	NA	NA	NA	0.0078	21.12	0.16
1998	NA	NA	NA	0.0084	22.73	0.17
1999	NA	NA	NA	0.0103	27.69	0.21
2000	NA	NA	NA	0.0106	28.68	0.21
2001	NA	NA	NA	0.0116	31.27	0.23
2002	NA	NA	NA	0.0121	32.68	0.24
2003	NA	NA	NA	0.0123	33.21	0.25
2004	NA	NA	NA	0.0125	33.73	0.25
2005	NA	NA	NA	0.0125	33.60	0.25
2006	NA	NA	NA	0.0126	33.87	0.25
2007	NA	NA	NA	0.0106	28.49	0.21
2008	NA	NA	NA	0.0118	31.84	0.24
2009	NA	NA	NA	0.0186	50.15	0.37
2010	NA	NA	NA	0.0231	62.25	0.46
2011	NA	NA	NA	0.0318	85.80	0.64

Year	Inventory Report, 2017 submission			Inventory Report, 2018 submission		
	Activity Data, Mt	Emissions, kt		Activity Data, Mt	Emissions, kt	
		CH_4	CO_2		CH_4	CO_2
2012	NA	NA	NA	0.0272	73.31	0.54
2013	NA	NA	NA	0.0267	71.85	0.53
2014	NA	NA	NA	0.0212	57.01	0.42
2015	NA	NA	NA	0.0163	43.84	0.33

Table 3.18. Results of the revision of emission in category 1.B.1.a

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Inventory Report, 2017 submission										
1. B. 1. a Column "Emissions CO_2, kt", subcategory "Coal mining and handling, Underground mines, Mining activities"	0.001	0.002	0.006	0.025	0.035	0.078	0.073	0.072	0.057	0.044
Inventory Report, 2018 submission										
1. B. 1. a Column "Emissions CO_2, kt", subcategory "Coal mining and handling, Underground mines, Mining activities"	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA	NO, NE,NA

3.3.1.7 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 2016, oil production in Ukraine was 1.6 Mt, which is 13.8 % lower compared to the same indication for 2015. For 2015, the activity data about oil production were taken from the SSSU and taking into account the analytical study [26] and for 2016 - in line with methodology aspects for 2015. In Ukraine, there is a well-developed system of oil transportation by pipeline transport. Pipelines provide for supply of oil to Ukrainian refineries and oil transit to Europe. The length of the pipeline with the diameter of 150 to 1200 mm is 4,767.3 km, and the input capacity - 114 Mt of oil per year, and the output one - 56.3 Mt of oil per year. Oil pumping is done by 51 oil pumping stations, where 176 oil transfer pumps with the total electric capacity of 357 MW are installed. To ensure reliable and uninterrupted operation of pipelines, 80 reservoirs with the capacity of more than 1 mln. m^3 are operated. In recent years, capacity utilization for transportation of oil through main pipelines was less than 35% and amounted to 14.5 Mt in 2016.

In 2016, Ukrainian refineries processed about 2.77 Mt of oil and gas condensate, which is 0.7% more than in 2015.

In 2016, GHG emissions in the category amounted to 1.7 Mt of CO_2-eq, the decrease with respect to 1990 is 60.5%, and 13.5% - to 2015.

3.3.2.1.2 Methodological issues

The data used for emission estimation in this category are presented in Table 3.19.

To estimate emissions in this category were used average Tier 1 default emission factors that presented in table 3.20.

For recalculation of the amount of oil extracted from the mass units into volumetric ones, the density of 0.825 t/m^3 was used. This value was determined based on data on oil density in API degrees for Ukraine (the value is 40.1).

Oil transportation in Ukraine is carried out mainly by pipelines. So, the default emissions factors for transportation of oil by the pipeline were used according to [1]. Since the volumes of oil transportation through the territory of Ukraine considerably exceed its own production volumes, the transformation of the amount of transported oil from mass units used by oil transportation enterprises into volumetric units was conducted based of the average density of the Russian Urals export blend - 0.865 t/m^3.

Emissions CH_4 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 types activity were not estimated either.

Table 3.19. Activity data for emission estimation in the category Oil (category 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[1]	16.9	3.0
2015	1.9[1]	16.8	2.7
2016	1.6[1]	14.57	2.8

[1] – in view of analytical study [26]

Table 3.20. 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 38.55 thousand km of gas pipelines, including 22.16 thousand km main pipeline and 16.39 thousand km gas pipeline branches, 12 underground gas storages (UGS), 702 gas pumping units (including electric ones - 158) with the total capacity of 5,443 MW, a developed system of gas distribution (GDS) and gas metering (GMS) 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 transit volume in 2016 amounted to 82.2 billion $m^{3.}$

Natural gas production in 2016 amounted to 21.74 billion m^3, which is 0.3% higher than the level of 2015. For 2016, the activity data about natural gas production was taken from the SSSU and taking into account the analytical study [26].

In 2016, GHG emissions in the category amounted to 27.43 Mt of CO_2-eq., the decrease with respect to 1990 is 54.5 %, and 11.8% higher than in 2015.

3.3.2.2.2 Methodological issues

The activity data used for emission estimation in this category are presented in table 3.21.

To estimate emissions in this category average Tier 1 default emission factors were used that presented in table 3.22.

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.

The observed redistribution in individual years is due to the structural changes in gas transmission companies, which submit reports to the statistical service, namely a change of economic activities. Nevertheless, the total volume of leakage from the transportation and distribution are regular trend.

Table 3.21. Activity data for emission estimation in the category Natural Gas (category 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

[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 gas transportation system of Ukraine received from PJSC "Ukrtransgaz" and PJSC "Ukrgazvydobuvannya" (see A2.6.1, A2.8) were used.

Table 3.22. 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, i.e. oil produced (1977.69 kt) and NG produced (21740.94 mln m^3).

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 5.79 % 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 23.48 % 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 3.7 %.

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 category 1.B.2.b "Natural gas", recalculations were made in the subcategory of residential and non-residential gas consumption, in connection with the correction of errors.

The results of the conversion of volumes of consumption of residential and non-residential gas for category 1.B.2.b are shown in Table 3.23.

Table 3.23. Results of conversion of volume of consumption of residential and non-residential gas in the category 1.B.2.b "Natural gas"

Year	Inventory Report, 2017 submission			Inventory Report, 2018 submission			Difference, %		
	Value, PJ	CO_2, kt	CH_4, kt	Value, PJ	CO_2, kt	CH_4, kt	Value	CO_2	CH_4
2013	1568.23	0.85	342.72	1572.56	0.89	359.07	0.3	4.7	4.8
2014	1415.63	0.69	314.69	1415.63	0.69	317.52	0.0	0.0	0.9
2015	900.12	0.79	191.61	1115.49	1.04	252.23	23.9	31.6	31.6

3.3.2.7 Category-specific planned improvements

In this category, no improvements 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	2015	2016	Change, % compared	
				to 1990	to 2015
CO_2, kt	110687.58	53362.73	54457.21	-50.80	2.05
CH_4, kt CO_2-eq.	1 393.13	596.50	646.82	-53.57	8.44
N_2O, kt CO_2-eq.	5 671.54	1 697.46	2022.44	-64.34	19.14
HFC, kt CO_2-eq.	-	775.59	889.00	-	14.62
PFC, kt CO_2-eq.	235.819	-	-	-	-
SF_6, kt CO_2-eq.	0.007631	19.397	24.111	315828.4	24.30
Total direct action greenhouse gases, kt CO_2-eq.	117 988.08	56451.68	58039.58	-50.809	2.813
Total direct action greenhouse gases, % of total emissions (without LULUCF)	12.46	17.70	17.11	-	-
NO_x, kt	40.89	17.73	19.89	-51.35	12.23
CO, kt	69.36	34.01	36.38	-47.55	6.98
NMVOC, kt	470.66	105.12	116.43	-75.26	10.76
SO_2, kt	149.09	53.73	57.59	-61.38	7.17
Indirect N_2O, kt CO_2-eq.	4.89	2.12	2.38	12,23	-51,35

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.

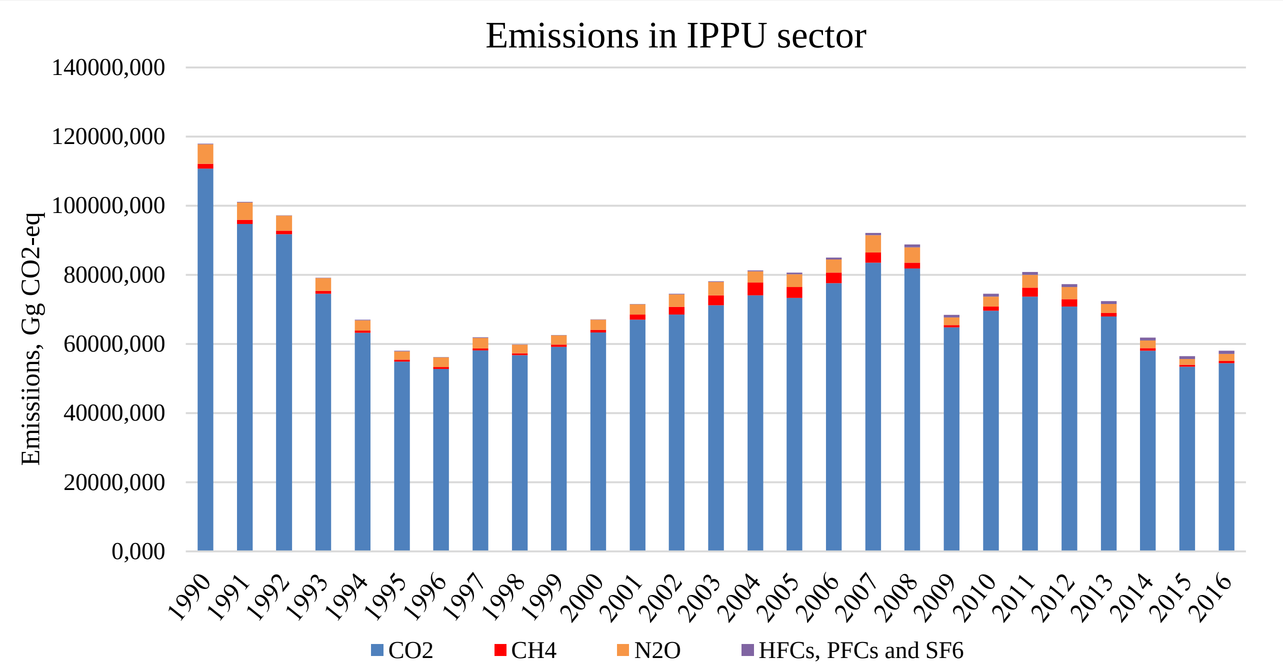

Fig. 4.1. Emissions of CO_2, CH_4, and N_2O in the sector Industrial Processes and Product Use, kt CO_2-eq.

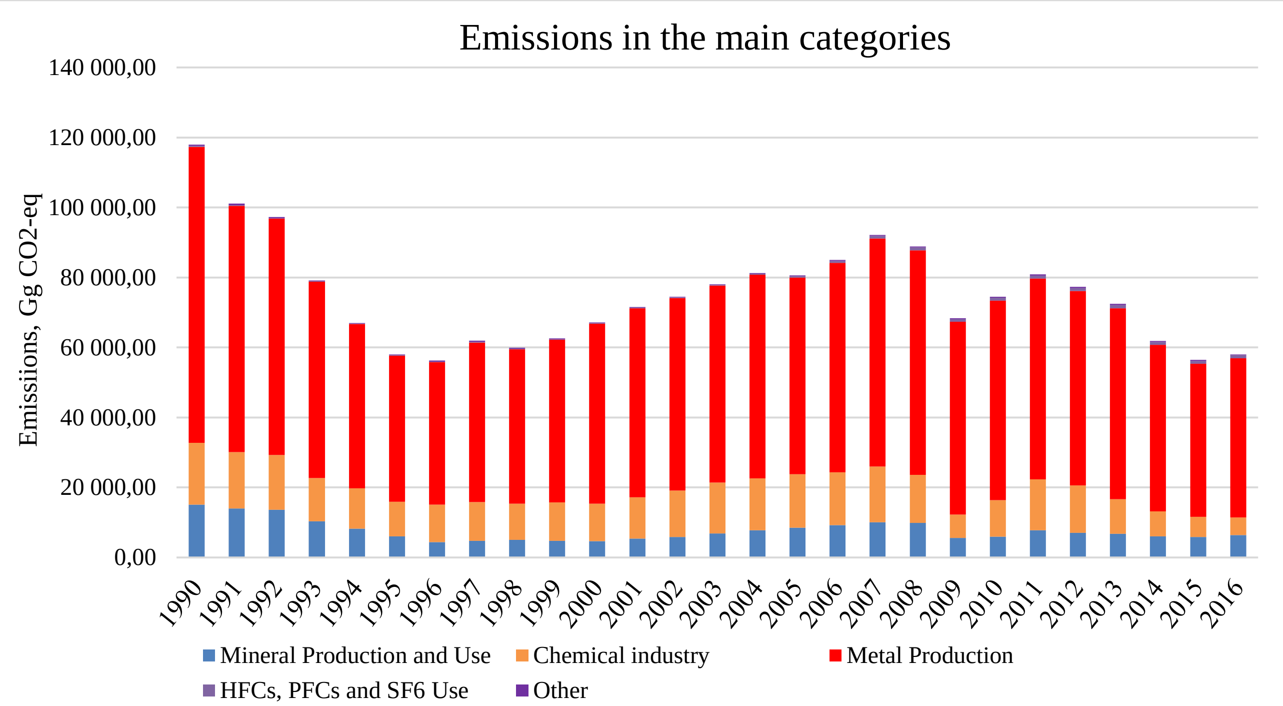

Fig. 4.2. Direct action greenhouse gas emissions in the major categories of the sector Industrial Processes and Product Use, kt CO_2-eq.

Growth of GHG emissions in 2016 compared to the previous year is due to the increase in industrial production by 2.8% according to the data of national statistics. The production in the metal industry increased by 6.8% and chemical industry by 1.1%, 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, ammonia, cement, and lime. CH_4 emissions in the industrial sector are mainly associated with 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.

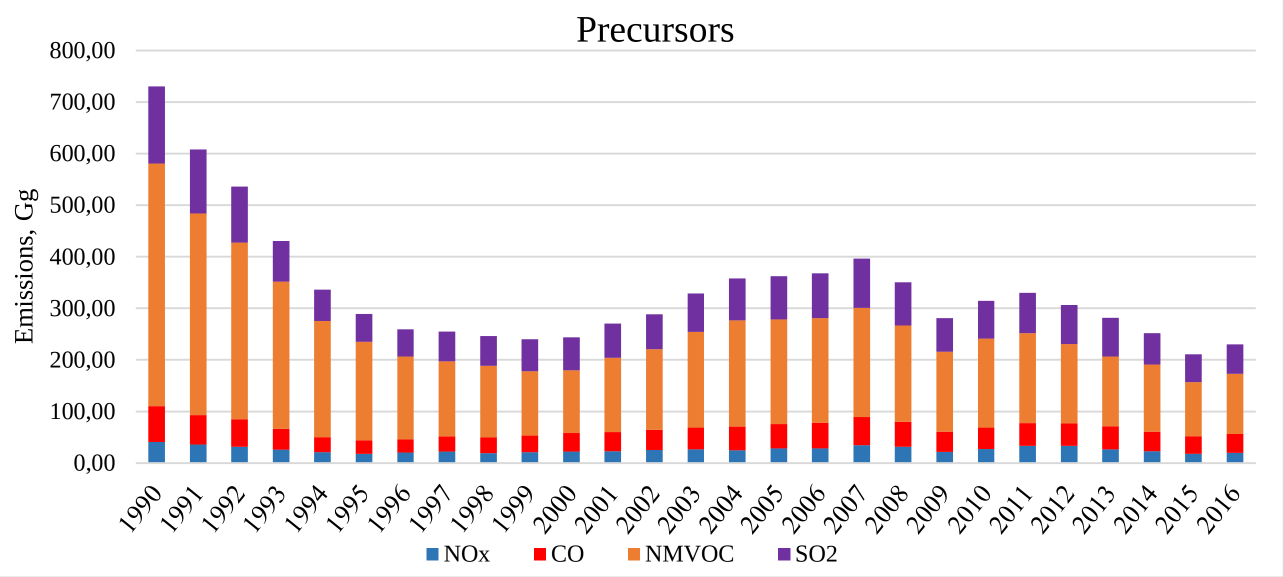

Fig. 4.3. Indirect action greenhouse gases and SO_2 emissions in the sector Industrial Processes and Product Use, kt

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

4.2.1 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 - 2016 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 2016

Category code		**2.A.1**	
Cement production, kt		9098.7	
Clinker production, kt		6687.396	
Gases		CO_2	SO_2
Emissions, kt		3622.85	2.73
Change in emissions compared to the previous year,%		10.54	2.82
Change in emissions compared to the baseline year,%		-61.46	-59.97
Emissions, % of the total emissions in the sector		6.65	4.74
Emissions, % of the total direct action GHG emissions in the sector		6.24	
Key category ("l" - level, "t" - trend)		l	
Detail level (Tier)		2	1
Correction factor for cement kiln dust, p.u.		1.02	
Emission factor, t/t		0.531	0.0003
Conditioned emission factor, t/t		0.542	
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.

4.2.2 Methodological issues

For estimation of CO_2 emissions, the emission estimation method using data of the amount of produced clinker (Tier 2 method) [1] 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 State Statistics Service of Ukraine [2]. For 2014 - 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] was taken into account in adjustment of amounts of cement and clinker production. Emission factors and cement kiln dust correction factors (CKD) were determined by default in accordance with 2006 IPCC Guidelines [1]. Receiving of baseline technological parameters made it possible to perform calculations of CO_2 emissions in accordance with the technological parameters at the cement enterprises of Ukraine.

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 2013-2016.

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.

4.2.3 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%.

4.2.4 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 the State Statistics Service of Ukraine 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.

4.2.5 Category-specific recalculations

In this category, no recalculations were made.

4.2.6 Category-specific planned improvements

In this category, no improvements are planned.

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

4.3.1 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 use of lime produced in 2016 is distributed as follows:

- metallurgy - 73%;
- sugar industry - 8%;
- construction - 4 %;
- other - 15%;

The largest consumer of lime is the metallurgical industry. The free lime market capacity in 2016 remained - approximately 641 kt of lime (slaked and quicklime), while its share of the total lime market increased to 20%.

The reduction of slaked lime production in the period from 2011 to 2016 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 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 4.3 shows the basic data on the results of GHG inventory in lime production.

Table 4.3. The basic data on the results of GHG inventory in lime production in 2016

Category code	2.A.2
Lime production, kt	3324.9
Emissions of CO_2, kt	2472.21
Change in CO_2 emissions compared to the previous year,%	-8.66
Change in CO_2 emissions compared to the baseline year,%	-51.73
Emissions, % of the total emissions in the sector	4.54
Emissions, % of the total direct action GHG emissions in the sector	4.26
Key category ("l" - level, "t" - trend)	l
Detail level (Tier)	2
Emission factor, t/t	0.768
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.

4.3.2 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 the State Statistics Service of Ukraine [2], with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] for adjustment of the amounts of lime production in 2014 - 2016. 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.

4.3.3 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 national statistics, 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%.

4.3.4 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.

4.3.5 Category-specific recalculations

In 2016 in this category recalculation of CO_2 emissions for 2011 - 2013 was made due to adjustment of the data of lime production according to the data obtained from State Statistics Service of Ukraine [2] (see Table 4.4).

Table 4.4 Recalculation of emissions from lime production in 2011 - 2013

2.A.2 Lime production	**2011**	**2012**	**2013**
CO_2			
Emissions (before recalculating), kt	3367.23	3325.81	2995.11
Emissions (after recalculating), kt	3419.66	3359.35	3028.77
Emission difference,%	1.56	1.01	1.12

4.3.6 Category-specific planned improvements

In this category, no improvements are planned.

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

4.4.1 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 2016

Category code	**2.A.3**	
Glass production, kt	1231.49	
Gas	CO_2	NMVOC
Emissions, kt	227.91	5.541
Change in emissions compared to the previous year, %	0.54	4.25
Change in emissions compared to the baseline year, %	31.56	23.77
Emissions, % of the total emissions in the sector	0.42	4.98
Emissions, % of the total direct action GHG emissions in the sector	0.39	
The key category	No	
Detail level (Tier)	3	1
Emission factor, t/t	0.185	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.

4.4.2 Methodological issues

The amount of glass produced was taken in accordance with data obtained from the State Statistics Service of Ukraine [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 [20] for adjustment of the amounts of glass production in 2014 - 2016. 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.

Discrepancies in the national CO_2 emissions factors for production of various types of glass are minor. Emissions from soda ash use in glass production were calculated based on data of soda ash content in furnace charge provided by the manufacturing enterprises and the CO_2 emission factor used in the calculations in category 2.A.4.b. Other Process Uses of Carbonates. Use of Soda Ash.

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

4.4.3 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%.

4.4.4 Category-specific QA/QC procedures

When performing estimations in this category and the scientific-research work [8], the general quality control procedures were applied in accordance with the requirements of Revised Guidelines IPCC [5]. As part of quality control procedures, a comparison of data of production of various types of glass with data of obtained from the State Statistics Service of Ukraine [2] was performed. As a result, the verification did not detect significant deviations.

4.4.5 Category-specific recalculations

In this category, no recalculations were made.

4.4.6 Category-specific planned improvements

In this category, no improvements are planned.

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

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

4.5.1.1 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 4.6 shows the results of the GHG inventory for use of limestone and dolomite.

Table 4.6. Basic data on CO_2 emission inventory results for use of limestone and dolomite in 2016

Category code	2.A.4.a	
Type of product	Ceramics	
	Limestone	Dolomite
Use, kt	13.617	138.829
Production, kt	3871.57	
Emissions of CO_2, kt	67.89	
Change in CO_2 emissions compared to the previous year,%	-1.96	
Change in CO_2 emissions compared to the baseline year,%	-39.25	
Emissions, % of the total emissions in the sector	0.12	
Emissions, % of the total direct action GHG emissions in the sector	0.11	
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	

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.

4.5.1.2 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 State Statistics Service of Ukraine [2], with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] for adjustment of the amounts of ceramics production in 2014 - 2016. 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].

4.5.1.3 Uncertainties and time series-consistency

The uncertainty of data of limestone and dolomite use in ceramics production was set at 2%. The uncertainty of CO_2 emission factors was set at 6%. The uncertainty of emission estimation in limestone and dolomite use in ceramics production amounts to 6.32 %.

4.5.1.4 Category-specific QA/QC procedures

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

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

4.5.2.1 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. Emissions from soda ash use in glass production were estimated in category 2.A.3 Glass production.

Table 4.7 shows the results of the GHG inventory in other soda ash use.

Table 4.7. Basic data of CO_2 emission inventory results for other soda ash use in 2016

Category code	**2.A.4.b**
Soda ash use, kt	20.27
Emissions of CO_2, kt	8.411
Change in CO_2 emissions compared to the previous year,%	224.20
Change in CO_2 emissions compared to the baseline year,%	-97.19
Emissions, % of the total emissions in the sector	0.016
Emissions, % of the total direct action GHG emissions in the sector	0.014
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

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.

4.5.2.2 Methodological issues

According to ERT recommendation in ARR 2013[11], estimation of CO_2 emissions from coke use for thermal decomposition of limestone in soda ash production was no performed because on enterprise-producer for thermal decomposition of limestone coke was not used. Since the data of fuel use (coke, anthracite, coal) are not available, the estimate of CO_2 emissions was calculated on the basis of data of soda ash use, not those on production 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 [20] for adjustment of the amounts of soda ash production in 2014 - 2016. Data of soda export and import was obtained from Ukrainian national statistics. Data of soda production was taken from annual report of enterprise-producer. Emission from soda ash use in glass production was excluded from emissions in this category and incuded in 2.A.3 Glass production.

4.5.2.3 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%.

4.5.2.4 Category-specific QA/QC procedures

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

4.5.2.5 Category-specific recalculations

In this category, no recalculations were made.

4.5.2.6 Category-specific planned improvements

In this category, no improvements are planned.

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

4.6.1 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 4.8 shows the basic data on the results of GHG inventory in ammonia production.

Table 4.8. The basic data on the results of GHG inventory in ammonia production in 2016

Category code	2.B.1				
Ammonia production, kt	2044.2				
Consumption of natural gas, M m^3	2152.89				
Gases	CO_2	CO	NO_x	NMVOC	SO_2
Emissions from production, kt	2662.89	0.012	2.044	0.183	0.061
Change in emissions compared to the previous year,%	-29.94	-22.59			
Change in emissions compared to the baseline year,%	-71.68	-57.97			
Emissions, % of the total emissions in the sector	4.89	0.033	10.27	0.16	0.11
Emissions, % of the total direct action GHG emissions in the sector	4.59				

Key category ("l" - level, "t" - trend)	l/t				
Method for determination of the emission factor	T3	D	D	D	D
Detail level (Tier)	3	1	1	1	1
Emission factor at production, kg/t	1.303	0.0006	1	0.009	0.003
Uncertainty of activity data, %	2				
Uncertainty of the emission factor, %	7				
Uncertainty of data on use of urea,%	5				
Uncertainty of the emission estimation, %	8.832				

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.7, Annex 3.1.1.

4.6.2 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 sub-division 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 statistical reporting form 1-P 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.

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.

4.6.3 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 2%. 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 8.832%.

4.6.4 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 data of ammonia production and consumption of natural gas for ammonia production provided by enterprises-producers in accordance with data of national statistics;
- comparison of the national CO_2 emissions factors with the default IPCC factors.

Analysis of data on ammonia production provided by enterprises shows that they coincide with the data of State Statistics Service of Ukraine [2] (the difference in 2016 is 0.009%), which is not essential.

4.6.5 Category-specific recalculations

In 2016 in this category recalculation of CO_2 emissions for 2015 was made due to adjustment of the data of natural gas consumption according to the data obtained from enterprises. Besides, recalculation of CO_2 emissions was carried out in this category in 2015 due to adjustment of the data of NCV of natural gas obrtained from passports-certificates of physical and chemical properties of natural gas in gas production and gas transportation companies of Ukraine (see Table 4.9).

Table 4.9 Recalculation of emissions from ammonia production in 2015

2.B.1 Ammonia production	**2015**
CO_2	
EF (before recalculating)	1.403
Emissions (before recalculating), kt	3703.45
EF (after recalculating)	1.439
Emissions (after recalculating), kt	3800.79
Emission difference,%	2.628

4.6.6 Category-specific planned improvements

In this category, no improvements are planned.

4.7 Nitric Acid Production (CRF category 2.B.2)

4.7.1 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 4.10 shows the basic data on the results of GHG inventory in nitric acid production.

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 4.10. The basic data on the results of GHG inventory in nitric acid production in 2016

Category code	**2.B.2**	
Nitric acid production, kt	1399.832	
Greenhouse gas	N_2O	NOx
Emissions from production, kt	6.299	13.998
Change in emissions compared to the previous year,%	20.99	
Change in emissions compared to the baseline year,%	-64.48	
Emissions, % of the total emissions in the sector	92.77	70.37
Emissions, % of the total direct action GHG emissions in the sector	3.23	
Key category ("l" - level, "t" - trend)	l	
Detail level (Tier)	3/2	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, %	2	
Uncertainty of the emission factor, %	5	
Uncertainty of the emission estimation, %	5.4	

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table A3.1.1.8, Annex 3.1.1.

4.7.2 Methodological issues

Emissions from nitric acid production on medium-pressure units UKL-7 for 1990 - 2008 were calculated using nitrogen oxide emission factor (7 kg/t), as default, according to 2006 IPCC Guidelines [1]. As a result of the introduction on the part of enterprises in 2009, the secondary catalysts for catalytic destruction of nitrous oxide, with the purpose to decomposition of N_2O emissions and automated emissions monitoring systems, in calculations of N_2O emissions for 2009 - 2016 nitrogen oxide emission factor (4.5 kg/t) was used, based on the expert judgment prepared by the Union of Chemists of Ukraine, 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" [12] as a weighted average of the emission factor at the enterprises producing nitric acid, for the medium-pressure units UKL-7. For one enterprise using low-pressure units, the default nitrous oxide 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).

4.7.3 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%.

4.7.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in production of nitric acid. As part of the quality control procedures, the following were performed:

- comparison of nitric acid production data in accordance with the data of the State Statistics Service of Ukraine and the enterprises-producers;
- the data on amounts of nitric acid production provided by the enterprises virtually coincide with the statistical data (the difference in 2016 is 0.22%, which is not essential).

4.7.5 Category-specific recalculations

In 2016 in this category recalculation of N_2O and NO_x emissions for 2011 - 2014 was made due to adjustment of the data of nitric acid production according to the data obtained from enterprises.

Table 4.11 Recalculation of emissions from nitric acid production in 2011 - 2014

2.B.2 Nitric acid production	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
N_2O						
Emissions (before recalculating), kt	6.606	8.094	10.598	10.757	9.311	7.11197
Emissions (after recalculating), kt	6.599	8.085	10.568	10.758	8.073	7.11205
Emission difference,%	-0.108	-0.111	-0.288	0.003	-13.290	0.001
NO_x						
Emissions (before recalculating), kt	14.534	17.980	23.163	23.369	20.661	15.6940
Emissions (after recalculating), kt	14.518	17.960	23.095	23.370	17.911	15.6938
Emission difference,%	-0.109	-0.111	-0.293	0.003	-13.309	0.001

4.7.6 Category-specific planned improvements

In this category, no improvements are planned.

4.8 Adipic Acid Production (CRF category 2.B.3)

4.8.1 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 A3.1.1.9 in Annex 3 and the CRF tables.

4.8.2 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.

4.8.3 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.

4.8.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in adipic acid production.

4.8.5 Category-specific recalculations

In this category, no recalculations were made.

4.8.6 Category-specific planned improvements

In this category, no improvements are planned.

4.9 Caprolactam, Glyoxal, and Glyoxylic Acid Production (CRF category 2.B.4)

4.9.1 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.
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.

4.9.2 Methodological issues

Data of caprolactam production was provided by the enterprises-producers. For estimation of N_2O emissions from caprolactam production, 2006 IPCC Guidelines [1], using Tier 1 method with default emission factor was used.

4.9.3 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.

4.9.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in caprolactam production.

4.9.5 Category-specific recalculations

In this category, no recalculations were made.

4.9.6 Category-specific planned improvements

In this category, no improvements are planned.

4.10 Carbide Production and Use (CRF category 2.B.5)

4.10.1 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 information of silicon and calcium carbide production was provided by the enterprises-producers and the State Enterprise "Cherkasky NIITEKHIM".

Table 4.12 shows data on CO_2 emissions from production and use of calcium carbide and CH_4 emissions from silicon carbide production.

Table 4.12. The basic data on the results of GHG inventory in carbide production and use in 2016

Category code	**2.B.4**	
Carbide Production and Use, kt	C	
Greenhouse gas	CO_2	CH_4
Emissions, kt	32.270	0.142
Change in emissions compared to the previous year,%	-8.357	-8.082
Change in emissions compared to the baseline year,%	-73.337	-5.379
Emissions, % of the total emissions in the sector	0.059	0.55
Emissions, % of the total direct action GHG emissions in the sector	0.055	0.0061
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	

4.10.2 Methodological issues

The data of calcium and silicon carbide production were provided by the enterprises-producers and confirmed by the State Enterprise "Cherkasky NIITEKHIM". 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].

4.10.3 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%.

4.10.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in production and use of calcium carbide.

4.10.5 Category-specific recalculations

In this category, no recalculations were made.

4.10.6 Category-specific planned improvements

In this category, no improvements are planned.

4.11 Titanium Dioxide Production (CRF category 2.B.6)

4.11.1 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 4.13 shows the basic data on the results of GHG inventory in titanium dioxide production.

Table 4.13. The basic data on the results of GHG inventory in dioxide titanium production in 2016

Category code	2.B.6
Titanium Dioxide Production, kt	141.755
Emissions of CO_2, kt	189.952
Change in CO_2 emissions compared to the previous year,%	2.22
Change in CO_2 emissions compared to the baseline year,%	-16.06
Emissions, % of the total emissions in the sector	0.35
Emissions, % of the total direct action GHG emissions in the sector	0.33
The key category	No
Detail level (Tier)	1
Method for determination of the emission factor	D
Uncertainty of activity data, %	5
Uncertainty of the emission factor, %	15
Uncertainty of the emission estimation, %	15.81

4.11.2 Methodological issues

Data of titanium dioxide production were provided by the enterprises-producers. For estimation of CO_2 emissions from titanium dioxide production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.11.3 Uncertainties and time-series consistency

The uncertainty of production data is estimated at 5%. 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%.

4.11.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in production of titanium.

4.11.5 Category-specific recalculations

In this category, no recalculations were made.

4.11.6 Category-specific planned improvements

In this category, no improvements are planned.

4.12 Soda Ash Production and Use (CRF category 2.B.7)

4.12.1 Category description

In Ukraine, soda ash production takes place at one plant with Solvay process (the synthesis process). At this plant, coke for thermal decomposition of limestone is not used. Since the data of fuel use (coke, anthracite, coal) are not available, the estimate of CO_2 emissions was calculated on the basis of data of soda ash use, not those on production, and it is accounted for in category 2.A.4.b. Other Uses of Soda Ash.

4.13 Petrochemical and Carbon Black Production (CRF category 2.B.8)

4.13.1 Category description

In this category, estimation of carbon dioxide andmethane 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, polystyrene, propylene, polypropylene, polyethylene, sulfuric acid, and phthalic anhydride was made.

Carbon black is used as a reinforcing component in production of rubbers and other plastic masses. In production of carbon black occurs emissions of CO_2, CH_4, SO_2, and all precursors GHGs - NO_x, CO and NMVOCs. Since 2007, statistics of carbon black production in Ukraine is confidential. Data of carbon black production in 2016 were provided by the enterprises-producers and State Enterprise "Cherkasky NIITEKHIM".

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. Since 2013, ethylene has not been produced in Ukraine, which was confirmed with data provided by the SE "Cherkasky NIITEKHIM".

Methanol (methyl alcohol) CH_3OH is obtained from carbon monoxide and hydrogen under pressure in the presence of catalysts, and also in dry distillation of wood. 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 2016 were provided by the enterprises-producers and the SE "Cherkasky NIITEKHIM".

Vinyl chloride monomer is an organic matter which is a simple chlorinated derivatives of ethylene, 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.

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 2016 were provided by enterprises-producers and the SE "Cherkasky NIITEKHIM" and State Statistics Service of Ukraine (statistical reporting form № 1-P).

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, propylene has not been produced in Ukraine, which was confirmed with data provided by the SE "Cherkasky NIITEKHIM".

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, polypropylene has not been produced in Ukraine, which was confirmed with data provided by the SE "Cherkasky NIITEKHIM".

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 2016 was received from the enterprises-producers and the SE "Cherkasky NIITEKHIM".

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 State Statistics Service of Ukraine (statistical reporting form № 1-P) 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 4.14 shows the basic data on the results of GHG inventory in this category.

Table 4.14. The basic data on the results of GHG inventory in the category Petrochemical and Carbon Black Production in 2016

Category code	2.B.5					
Gases	CO_2	CH_4	NO_x	CO	NMVOC	SO_2
Emissions in production, kt	188.88	2.069	1.081	2.162	0.051	6.326
Change in emissions compared to the previous year,%	30.60	30.60	30.60	30.60	30.42	9.09
Change in emissions compared to the baseline year,%	-90.37	-79.85	-72.27	-72.27	-92.58	-87.61
Emissions, % of the total emissions in the sector	0.35	7.84	5.43	5.94	0.046	10.98
Emissions, % of the total direct action GHG emissions in the sector	0.32	0.09				
The key category	No	No				
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 A3.1.1.10, Annex 3.1.1.

4.13.2 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" 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 the State Statistics Service of Ukraine [2], with using analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] for adjustment of the amounts of petrochemical products production in 2014 [20].

4.13.3 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%.

4.13.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in chemical production.

4.13.5 Category-specific recalculations

In 2016 recalculation of NMVOC emissions was made in this category for the 2015 due to adjustment of the data of polystyrene production according to the data obtained from State Statistic Service of Ukraine [2] (see Table 4.15).

Table 4.15 Recalculation of emissions from petrochemical production in 2015

2.B.8 Petrochemical Production	**2015**
NMVOC	
Emissions (before recalculating), kt	0.0386
Emissions (after recalculating), kt	0.0389
Emission difference,%	0.716

4.13.6 Planned improvements

In this category, no improvements are planned.

4.14 Iron and Steel Production (CRF category 2.C.1)

4.14.1 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". Table 4.16 shows the basic data on the results of GHG inventory in iron and steel production.

Table 4.16 Basic data on the results of GHG inventory in iron and steel production in 2016

Category code	**2.C.1**							
Iron production, kt	23559.500							
Steel production, kt	24196.0							
Sinter production, kt	34383.0							
Pellet production, kt	22386.0							
Consumption of natural gas, M m3	1.350							
Limestone use, kt	7160.4							
Dolomite use, kt	250.6							
Gases	All GHGs	CO_2	CH_4 (pig iron)	CH_4 (sinter)	NO_x	CO	NMVOC	SO_2
Emissions, kt	43579.978	42989.719	21.203	2.406	2.13	30.69	7.56	47.19
Change in emissions compared to the previous year,%	4.17	4.13	7.76	2.40	7.26	7.76	3.91	7.75
Change in emissions compared to the baseline year,%	-46.04	-46.02	-47.56	-43.57	-48.10	-47.52	-45.99	-47.61
Emissions, % of the total emissions in the sector		78.94	81.96	9.30	10.70	84.36	6.8	81.94
Emissions, % of the total direct action GHG emissions in the sector	75.09	74.07	0.913	0.104				
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		1.55	0.0009	0.00007				
Emission factor for steel, t/t		0.133						

Emission factor for limestone, kg/t		0.4338						
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, %		2.02	5					
Uncertainty of the emission factor, %		2.54	20					
Uncertainty of the emission estimation, %		3.25	20.6					

The reduction in emissions from iron and steel production in 2016 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 2016 compared to 2015 - to an icrease in the total production of iron and steel, as well as in coke consumption for iron and steel production. As well as a result of application at metallurgical enterprises of pulverized coal after the 2008/2009 crisis. Activity data, emission factors, and GHG emissions for the entire time series in this category are listed in Tables A3.1.1.11, annex A3.1.1.12.

4.14.2 Methodological issues

4.14.2.1 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 and of coke consumption, coal, and natural gas for estimation of emissions from iron production were obtained from the State Statistics Service of Ukraine [2, 21]. 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 from the enterprises-producers. For 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] was taken into account in adjustment of amounts of pig iron production and carbon content in pig iron and coke. 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" [14]. 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 sub-division 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 2016.

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].

4.14.2.2 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 [20] 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.

As a result of conducted scientific-research work was identified the national emissions factors in steel production, which are within the ranges:

- (in 2016 - 133 kg/t) - for steel produced in the open hearth furnaces;
- (in 2016 - 142 kg/t) - for steel produced in the basic oxygen furnaces;
- (in 2016 – 8.8 kg/t) - for steel produced in the electric arc furnaces;
- (in 2015 - 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].

4.14.2.3 Sinter and Pellet Production

In statistical reporting Form 4-MTP, 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.

4.14.2.4 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. For 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] was taken into account in adjustment of amounts of limestone, dolomite limestone, and dolomite consumption.

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 2016 reached 0.4348 t/t.

4.14.3 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 studies [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 0.83%.

The uncertainty of emission factors for iron and steel production is estimated at the level of, respectively, 2.75% and 1.73%.

Taking into account emissions from iron and steel production, the total uncertainty of the activity data for production of iron and steel is 2.02%, the uncertainty of emission factors – 2.54%, and the uncertainty of emission volumes – 3.25%.

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%.

4.14.4 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 and steel production in statistical reporting form 1-P with those provided by Association "Metallurgprom";
- analysis of data of consumption of reducing agents (coke, coal, and natural gas) in iron production in statistical reporting form 4-MTP and those provided by enterprises-producers;
- carbon balance analysis in the blast furnace process (Annex 3.1.4);
- analysis of the coke balance in Ukraine (Annex 2.8).

4.14.5 Category-specific recalculations

In 2016, recalculation of CO_2 emissions for 1990 – 2003 and 2008 in this category was due to correction of the data of limestone and dolomite consumption in steel production. Also recalculation of CO_2, CO, NO_x, NMVOC and SO_2 emissions for the 2011 – 2015 was made due to correction of the data of steel production and raw materials consumption in accordance with data obtained from enterprises-producers. Besides, in connection with clarification of data of net calorific value (NCV) of natural gas obtained from passports-certificates of physical and chemical properties of natural gas in gas production and gas transportation companies of Ukraine and carbon content in coal according to the data obtained from enterprises-producers (see Table 4.17).

Table 4.17 Recalculation of emissions from iron and steel production in 1990 – 2015

2.C.1 Iron and Steel Production	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
CO_2								
Emissions (before recalculating), kt	79 645.369	66 005.880	64 561.236	53 463.483	44 428.672	39 259.218	38 254.306	43 045.408
Emissions (after recalculating), kt	79 689.693	66 045.404	64 597.170	53 489.434	44 440.765	39 268.086	38 261.732	43 051.697
Emission difference,%	0.056	0.060	0.056	0.049	0.027	0.023	0.019	0.015
2.C.1 Iron and Steel Production	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2008**	
CO_2								
Emissions (before recalculating), kt	41 896.268	44 081.955	48 329.592	50 828.042	51 867.136	52 869.640	60 305.346	
Emissions (after recalculating), kt	41 902.387	44 087.339	48 336.271	50 836.302	51 875.326	52 878.892	60 301.832	
Emission difference,%	0.015	0.012	0.014	0.016	0.016	0.018	-0.006	

2.C.1 Iron and Steel Production	2011	2012	2013	2014	2015
CO_2					
Emissions (before recalculating), kt	54 361.971	52 649.294	51 733.02	44 117.09	40 908.707
Emissions (after recalculating), kt	54 351.275	52 645.869	51 853.451	44 492.986	41 286.555
Emission difference,%	-0.020	-0.007	0.233	0.852	0.924
CO					
Emissions (before recalculating), kt	37.6268	37.1186	37.9036	32.3137	
Emissions (after recalculating), kt	37.6271	37.1190	37.9034	32.3137	
Emission difference,%	0.00091	0.00097	-0.00053	0.0000029	
NO_x					
Emissions (before recalculating), kt	2.6842	2.5768	2.7190	2.300399	
Emissions (after recalculating), kt	2.7103	2.6043	2.7046	2.300402	
Emission difference,%	0.97	1.07	-0.53	0.0001161	
NMVOC					
Emissions (before recalculating), kt	9.0159	9.2360	9.4853		
Emissions (after recalculating), kt	9.0252	9.2457	9.4802		
Emission difference,%	0.10	0.11	-0.05		
SO_2					
Emissions (before recalculating), kt	57.8700	57.0528	58.3002		
Emissions (after recalculating), kt	57.8820	57.0654	58.2936		
Emission difference,%	0.021	0.022	-0.011		

4.14.6 Category-specific planned improvements

In this category, no improvements are planned.

4.15 Ferroalloys Production (CRF category 2.C.2)

4.15.1 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 sub-divided 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 4.18 shows the basic data of GHG inventory for carbon dioxide and methane in production of ferroalloys in Ukraine for 2016.

Table 4.18. The basic data on the results of GHG inventory in ferroalloys production in 2016

Category code	2.C.2	
Ferroalloys Production, kt	1188.349	
Limestone use, kt	15.83	
Gas	CO_2	CH_4
Emissions, kt	1848.51	0.051
Change in emissions compared to the previous year,%	-3.75	-45.91
Change in emissions compared to the baseline year,%	-47.68	-91.64
Emissions, % of the total emissions in the sector	3.39	0.19
Emissions, % of the total direct action GHG emissions in the sector	3.18	0.0022
Key category ("l" - level, "t" - trend)	l	
The level of detail for ferroalloys (Tier)	3	1
Emission factor, t/t	1.56	0.001
Method for determination of the emission factor for ferroalloys	CS	D
Uncertainty of activity data, %	7.1	5.25
Uncertainty of the emission factor, %	5	31.25
Uncertainty of the emission estimation, %	8.7	31.68

Activity data, emission factors, and GHG emissions throughout the entire time series in this category are shown in Table 3.1.1.13, Annex 3.1.1.

4.15.2 Methodological issues

As the activity data in the inventory of emissions in this category, statistical data of ferroalloys production provided by the the State Statistics Service of Ukraine [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 [20] 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 production obtained from the five largest ferroalloys enterprises-producers. 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 4.23. 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.

4.15.3 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 7.1%. 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 2016 was 8.7%. The uncertainty of estimates of methane emissions in production of ferroalloys for 2016 was 31.68 %.

4.15.4 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;

- comparison of ferroalloy production data provided by the State Statistics Service of Ukraine [2] and ferroalloys enterprises-producers;

Activity data meet the statistical and industry data about volumes of ferroalloy production.

4.15.5 Category-specific recalculations

In 2016 in this category recalculation of CO_2 emissions for the 2015 was made due to adjustment of the data of ferroalloys production according to the data obtained from enterprises (see Table 4.19).

Table 4.19 Recalculation of emissions from ferroalloy production in 2015

2.C.2 Ferroalloys Production	2015
CO_2	
EF (before recalculating)	1.769
Emissions (before recalculating), kt	1910.54
EF (after recalculating)	1.758
Emissions (after recalculating), kt	1920.44
Emission difference,%	0.518

4.15.6 Category-specific planned improvements

In this category, no improvements are planned.

4.16 Aluminum Production (CRF category 2.C.3)

4.16.1 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 production plant in Ukraine, since 2010 till 2016 aluminum production was stoped. Estimation of GHG emissions in 2016 was no performed in this category.

4.16.2 Methodological issues

Data of aluminium production was provided by the enterprises-producers. 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.

4.16.3 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.

4.16.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in aluminium production.

4.16.5 Category-specific recalculations

In this category, no recalculations were made.

4.16.6 Category-specific planned improvements

In this category, no improvements are planned.

4.17 Magnesium Production (CRF category 2.C.4)

There is no magnesium production in Ukraine, therefore emissions in this category are not estimated.

4.18 Lead Production (CRF category 2.C.5)

4.18.1 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 4.20 shows the basic data of GHG inventory for carbon dioxide in lead production in Ukraine for 2016.

Table 4.20. The basic data on the results of GHG inventory in lead production in 2016

Category code	2.C.5
Lead Production, kt	36.702
Gas	CO_2
Emissions, kt eq.	19.085
Change in emissions compared to the previous year,%	8.81
Change in emissions compared to the baseline year,%	-13.64
Emissions, % of the total emissions in the sector	0.035
Emissions, % of the total direct action GHG emissions in the sector	0.033
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

4.18.2 Methodological issues

Data of lead production were obtained from the State Statistics Service of Ukraine. For estimation of CO_2 emissions from lead production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.18.3 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 2016 was 50.99%.

4.18.4 Category-specific QA/QC procedures

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

4.18.5 Category-specific recalculations

In this category, no recalculations were made.

4.18.6 Category-specific planned improvements

In this category, no improvements are planned.

4.19 Zinc Production (CRF category 2.C.6)

4.19.1 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 4.21 shows the basic data of the inventory for carbon dioxide in zinc production in Ukraine for 2016.

Table 4.21. The basic data on the results of GHG inventory in zinc production in 2016

Category code	2.C.6
Zinc Production, kt	C
Gas	CO_2
Emissions, kt eq.	1.132
Change in emissions compared to the previous year,%	-7.50
Change in emissions compared to the baseline year,%	-95.33
Emissions, % of the total emissions in the sector	0.002
Emissions, % of the total direct action GHG emissions in the sector	0.0019
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

4.19.2 Methodological issues

Data of zinc production were taken from State Statistics Service of Ukraine[2]. For estimation of CO_2 emissions from zinc production, 2006 IPCC Guidelines [1] with default emission factors were used.

4.19.3 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 2016 was 50.99%.

4.19.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions in zinc production.

4.19.5 Category-specific recalculations

In this category, no recalculations were made.

4.19.6 Category-specific planned improvements

In this category, no improvements are planned.

4.20 Lubricant Use (CRF category 2.D.1)

4.20.1 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

Table 4.22 shows the basic data on the results of GHG inventory in lubricant use.

Table 4.22. The basic data on the results of GHG inventory in lubricant use in 2016

Category code	**2.D.1**
Lubricant Use, TJ	7834.641
Emissions of CO_2, kt	114.909
Change in CO_2 emissions compared to the previous year,%	-2.05
Change in CO_2 emissions compared to the baseline year,%	-62.30
Emissions, % of the total emissions in the sector	0.21
Emissions, % of the total direct action GHG emissions in the sector	0.20
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, %	6
Uncertainty of the emission factor, %	50.09
Uncertainty of the emission estimation, %	50.45

Activity data, emission factors, and GHG emissions throughout the entire time-series in this category are shown in Table A3.1.1.15, Annex 3.1.1.

4.20.2 Methodological issues

Estimation of emissions from lubricants use was carried out in accordance with 2006 IPCC Guidelines (Tier 1) with application of Oxidised During Use (ODU) and the default carbon content factor [1]. To avoid double counting between the Energy and IPPU sectors, data of lubricants non-energy consumption from 1998 till 2016 were obtained from the State Statistics Service of Ukraine [21], and consumption data from 1990 till 1997 were taken according to the IEA [22], which are not accounted in emission estimations in the "Energy sector". For 2014 - 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] was taken into account in adjustment of amounts of lubricants consumption.

4.20.3 Uncertainties and time-series consistency

The uncertainty of data of lubricants consumption obtained from statistical data is taken at 6%. 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 50.448%.

4.20.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation for GHG emissions in lubricant use.

4.20.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.20.6 Category-specific planned improvements

In this category, no improvements are planned.

4.21 Paraffin Wax Use (CRF category 2.D.2)

4.21.1 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 4.23 shows the basic data on the results of GHG inventory in wax use.

Table 4.23. The basic data on the results of GHG inventory in solid paraffin wax use in 2016

Category code	2.D.2
Solid Paraffin use, TJ	703.223
Emissions of CO_2, kt	10.314
Change in CO_2 emissions compared to the previous year,%	-1.85
Change in CO_2 emissions compared to the baseline year,%	-91.60
Emissions, % of the total emissions in the sector	0.019
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	0,589
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 A3.1.1.16, Annex 3.1.1.

4.21.2 Methodological issues

Estimation of emissions from solid paraffins use was carried out in accordance with 2006 IPCC Guidelines (Tier 1) with application of Oxidised During Use (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 State Statistic Service of Ukraine [2, 23]. For 2014 - 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] was taken into account in adjustment of amounts of solid 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.

4.21.3 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%.

4.21.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in paraffin wax use.

4.21.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.21.6 Category-specific planned improvements

In this category, no improvements are planned.

4.22 Asphalt Production and Use (CRF category 2.D.3)

4.22.1 Asphalt roofing (CRF category 2.D.3.a.1)

4.22.1.1 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 4.24 shows the basic data of the results of GHG inventory in construction and roofing bitumen production.

Table 4.24. The basic data on the results of GHG inventory in construction and roofing bitumen production in 2016

Category code	**2.D.3.1**	
Bitumen Production, t	1.18	
Gases	CO	NMVOC
Emissions, tons	0.000012	0.0000059
Change in emissions compared to the previous year,%	-47.45	
Change in emissions compared to the baseline year,%	-99.67	
Emissions, % of the total emissions in the sector	0.000033	0.0000053
Method for determination of the emission factor	D	D
Detail level (Tier)	1	1
Emission factor, n/t	0.00001	0.000005

4.22.1.2 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 State Statistic Service of Ukraine [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.

4.22.1.3 Uncertainties and time-series consistency

The uncertainty of CO and NMVOC emission estimation results was not determined in this category.

4.22.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions from construction and roofing bitumen production.

4.22.1.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.22.1.6 Category-specific planned improvements

In this category, no improvements are planned.

4.22.2 Road paving with asphalt (CRF category 2.D.3.a.2)

4.22.2.1 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 4.25 shows the basic data on the results of GHG inventory in road paving with asphalt.

Table 4.25. The basic data on the results of GHG inventory in road paving with asphalt in 2016

Category code	**2.D.3.a.2**			
Production of road bitumen, kt	27.3			
Gases	NOx	CO	NMVOC	SO_2
Emissions from production, kt	0.000972	0.00546	0.000628	0.000483
Emissions from paving, kt	0	0	0.437	0
Change in emissions compared to the previous year,%	58.72			
Change in emissions compared to the baseline year,%	-98.70			
Emissions at production, % of the total in the sector	0.0048	0.015	0.00056	0.00084
Emissions at paving, % of the total in the sector			0.23	
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	0	0.016	0

4.22.2.2 Methodological issues

Road bitumen production volumes was obtained from State Statistic Service of Ukraine [2]. In accordance with 2013 EMEP/EEA recommendations [6] the default emission factors of GHG emissions for asphalt production were used.

4.22.2.3 Uncertainties and time-series consistency

The uncertainty of NO_x, CO, NMVOC and SO_2 emission estimation results was not determined in this category.

4.22.2.4 Category-specific QA/QC procedures

The general quality control and assurance procedures were applied to estimation of GHG emissions at road paving with asphalt.

4.22.2.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.22.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.23 Solvents Use (CRF category 2.D.3.b)

4.23.1 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") were used.

NMVOC emissions in the Solvents Use category in 2016 amounted to 46.25 kt, having decreased compared to the baseline 1990 (274.44 kt) by -83.15%. 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.

4.23.2 Varnishes and Paints Use (CRF category 2.D.3.b.1)

4.23.2.1 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 [16].

In accordance to results of the current inventory, NMVOC emissions from paints use in Ukraine in 2016 amounted to 37.32 kt, having decreased compared to the baseline 1990 (154.16 kt) by 75.78% 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.

4.23.2.2 Methodological issues

In this inventory, for the time series of 1990-2016 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 [15], which was implemented by the Innovation Center "Ecosystem".

The basis of NMVOC emission calculations in this category, in accordance with [15], 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:

$$Q_t = \left(P \cdot \frac{K_{org}}{100} \cdot \frac{K_{P_{org}}}{1000}\right) + \left(P \cdot \frac{K_w}{100} \cdot \frac{K_{P_w}}{1000}\right), \qquad (1)$$

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:

1) 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);
2) by solvent type (organic-based coatings, water-based coatings);
3) by the coating use structure according to the type of use and the type of solvent;
4) by the inventory number in the time-series of 1990-2016.

The basis of the activity data is data of the amount of coating consumption in Ukraine in 1990 - 2016 taken based on production, exports, and imports data obtained from State Statistic Service of Ukraine[2, 23].

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 [15] 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 4.26.

Table 4.26. 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.

4.23.2.3 Uncertainties and time-series consistency

For emissions in this category, uncertainties were not estimated.

4.23.2.4 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;

4.23.2.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.23.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.23.3 Degreasing and Dry Cleaning (CRF category 2.D.3.b.2)

4.23.3.1 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 2016 amounted to 1.902 kt, which is 89.67% less than the same indicator for 1990 (18.41 kt). Emission data for the entire time series are displayed in Fig. 4.4.

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.

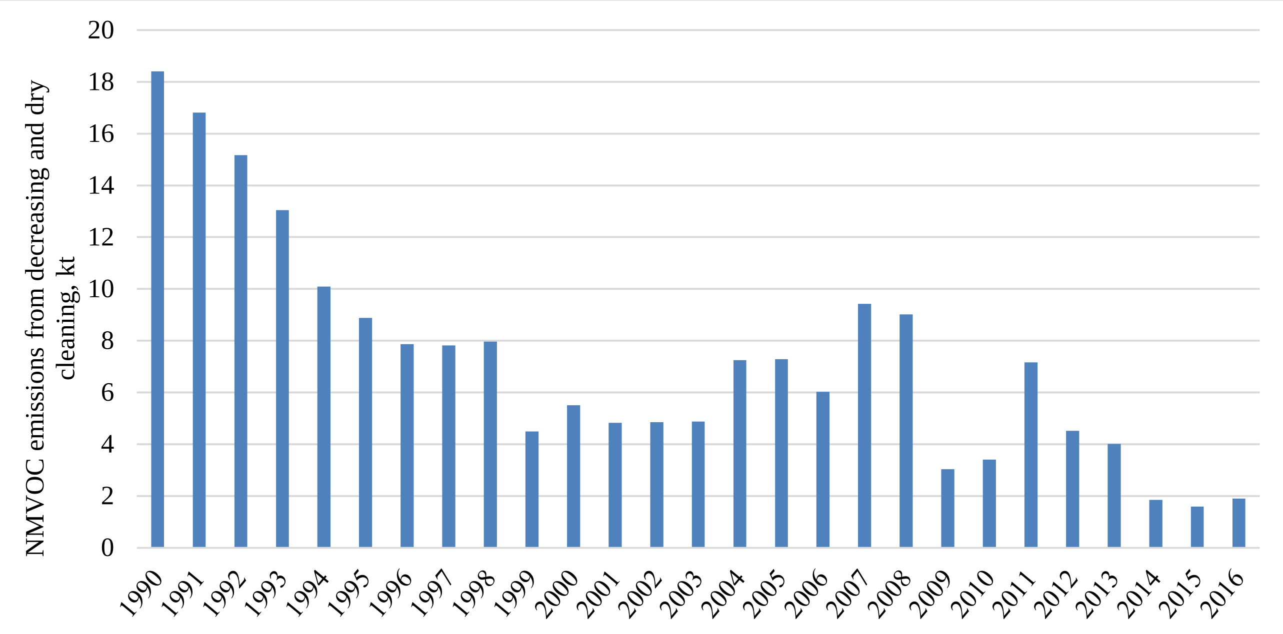

Figure 4.4. NMVOC emissions from degreasing and dry cleaning

4.23.3.2 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. To obtain them, statistical reporting form № 4-MTP was used, according to which from the data of final non-energy consumption of white spirits and technical kerosene data on their consumption as ingredients in paint and varnish production were excluded. Data of trichlorethylene and tetrachlorethylene (perchlorethylene) imports were provided by the national statistics of Ukraine. 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 [17].

4.23.3.3 Uncertainties and time-series consistency

For emissions in this category, uncertainties were not estimated.

4.23.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of emissions in the category.

4.23.3.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.23.3.6 Category-specific planned improvements

In this category, no improvements are planned.

4.23.4 Chemical Products: Production and Processing (CRF category 2.D.3.b.3)

4.23.4.1 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 2016, NMVOC emissions from production and processing of chemical products amounted to 7.019 kt, which is 93.11% less in relation to the baseline 1990 (101.9 kt). The emissions decrease in the periods of 1990-2000 and 2004-2014 are due to the persistent downward trend in oil refining in Ukraine. Detailed information of emissions in the category is presented in Fig. 4.5.

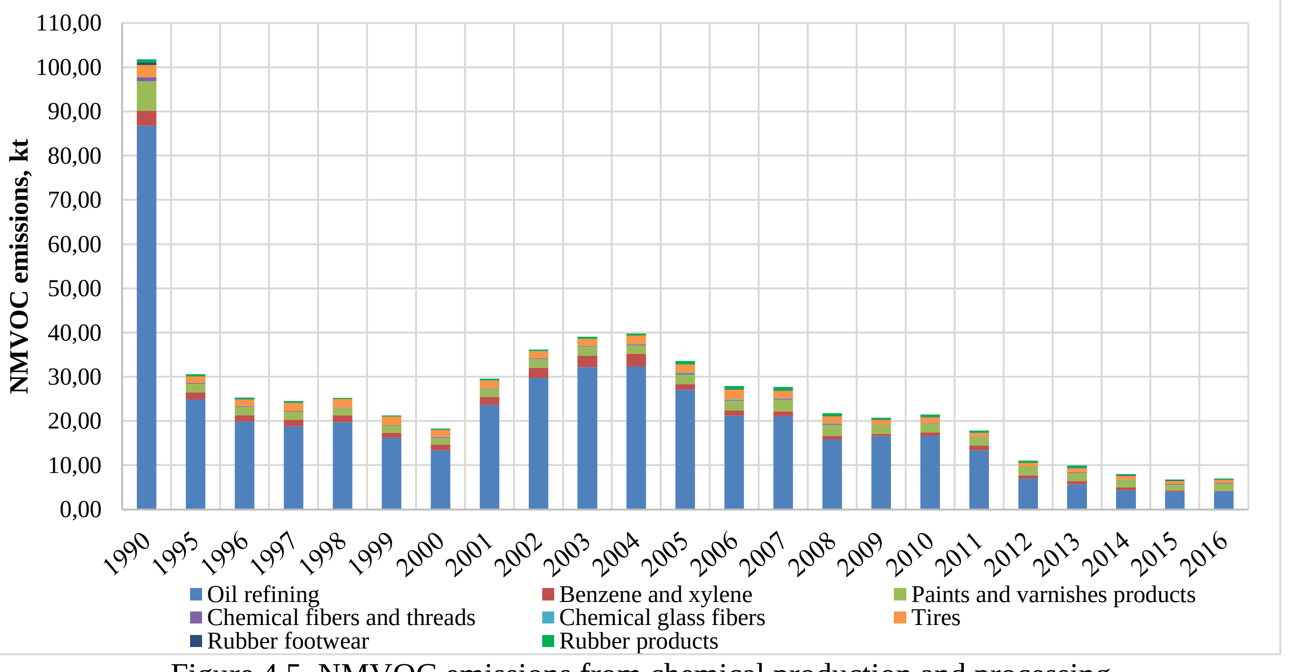

Figure 4.5. NMVOC emissions from chemical production and processing

4.23.4.2 Methodological issues

The data of volumes of chemical production and primary oil refining were taken according to national statistics (form № 1-P).

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 [18]) were used, which are similar to Ukrainian chemical industry technologies.

4.23.4.3 Uncertainties and time-series consistency

For emissions in this category, uncertainties were not estimated.

4.23.4.3 Category-specific QA/QC procedures

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

4.23.4.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.23.4.6 Category-specific planned improvements

In this category, no improvements are planned.

4.24 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.

4.25 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.

4.25.1 Refrigeration and Air Conditioning Systems

4.25.1.1 Refrigeration Equipment

4.25.1.1.1 Category description

The category of refrigeration equipment includes domestic, commercial, industrial, and transport (including maritime) equipment (systems, installations, machinery, plants, etc.). In 2016, the level of disaggregation of the refrigeration equipment category was deepened to four key subcategories.

In 2016 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 2016 refrigerants for domestic refrigerators were not consumed.

More than 20 producers in Ukraine manufacture commercial and industrial refrigeration equipment. As part of preparation of the National Inventory Report, 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 and HFC-404a are used.

In accordance with provisional main findings identified by the ERT calculations of emissions from disposal in commercial 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 Ukrainian state statistics data.

Table 4.27 summarizes results of GHG inventory in production and operation of refrigeration equipment in Ukraine in 2016.

Table 4.27 Basic data on results of GHG inventory in production and operation of refrigeration equipment in Ukraine in 2016

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**
Activity data										
Filled into new manufactured products (primary filling + tightness test), t	13.33	0.913	1.067	0.0	1.910	0.00023	0.00023	4.262	0.615	0.727
HFC-balance after the initial filling, t	13.06	0.895	1.045	0.0	1.853	0.00022	0.00022	4.265	0.649	0.767
Amount of HFC in exported equipment, t	6.65	0.0033	0.0029	0.0	1.149	-	-	-	-	-
Amount of HFC in imported equipment, t	25.54	5.52	3.913	36.25	2.719	0.229	0.164	0.0031	0.0339	0.04
In operating systems (average annual stocks)	150.02	38.257	35.539	852.19	27.529	7.828	4.008	6.639	2.660	3.144
Category characteristics and estimated factors										
Key category	No	No	No	No	No	No	No	No	No	No
Detail level (Tier)	2a	2a	2a	2b	2b	2a	2b	2a	2a	2a
Method for determination of the emission factor	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
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
Average life of equipment	15	15	15	18	25	25	25	15	15	15
GHG emissions										
HFCs emissions										
at the primary (initial) filling of the equipment(from manufacturing), t	0.266	0.0182	0.021	0.0	0.057	0.000007	0.000007	0.0852	0.0123	0.0145

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**
at exploitation of the equipment(from stocks), t	22.5	5.739	5.331	4.26	6.88	1.957	1.002	0.996	0.399	0.472
from liquidation of the equipment, t	20.53	3.129	3.298	-	-	-	-	0.066	0.0896	0.106
Emissions of HFCs in the refrigeration equipment category, total, t	43.30	8.886	8.650	4.26	6.94	1.957	1.002	1.146	0.501	0.592
Global Warming Potential (GWP), t $CO_{2-eq.}$ /t	1430	3500	4470	1430	1430	3500	4470	1430	3500	4470
GHG emissions, kt of CO_{2-eq}	61.92	31.10	38.668	6.093	9.92	6.849	4.479	1.640	1.753	2.64
Change in emissions compared to the previous year,%	94.64	57.43	59.41	3.92	-14.01	-22.74	-21.78	42.88	-28.72	-28.72
Emissions, % of the total direct action GHG emissions in the sector	0.23			0.01	0.037			0.01		
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.*

4.25.1.1.2 Methodological issues

4.25.1.1.2.1 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. The sharp increase in the use of HFC-134a in 2016 explains by an increase in imports of HFC-containing equipment mainly containing HFC-134a, in accordance with the data of the Fiscal Service of Ukraine

For 2014 - 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] 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 assumed life time of the domestic equipment is 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 of the scientific research institute Cherkassy NIITECHIM what allow to use of 18 years as lifetime which does not contradict with IPCC 2006[1].

4.25.1.1.2.1 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 - 2016, such as "Ukrzaliznytsia" and "Thermo king Ukraine" (the largest certified company 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].

4.25.1.1.3. 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 2016.

The calculated uncertainty of the activity data in the category of domestic refrigeration equipment in 2016 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 sub-category of domestic refrigeration equipment in 2016 was 20.6%, commercial refrigeration systems - 24.37%, industrial cooling systems - 32.78% and transport refrigeration - 24.37%. The total emission estimation uncertainty in 2016 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%.

4.25.1.1.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.25.1.1.5. Category-specific recalculations

In 2016, recalculation of HFC-134a, HFC-125 and HFC-143a emissions from transport refrigeration was made for the whole time series due to changes in calculation of Bank in existing equipment. Recalculation of HFC-134a, HFC-125 and HFC-143a emissions from commercial and transport refrigeration was conducted due to correction of the data on the amount of HFCs in imported equipment in accordance with data obtained from enterprises for the period of 2013 – 2015. And also recalculation was performed due to allocation of the emissions from the end of the lifetime of HFCs equipment for commercial and transport refrigeration for the period of 2014 - 2015.

Table 4.28 Recalculation of emissions from HFC use in refrigeration equipment for 2013-2015

2.F.1.A Commercial refrigeration	**2013**		**2014**		**2015**			
Emissions (before recalculation) $CO_{2\text{-eq}}$, kt	78.29592244		76.06934416		74.338			
Emissions (after recalculation) $CO_{2\text{-eq}}$, kt	78.29592294		76.06934453		75.825			
Emission difference,%	-0.00000065		-0.00000049		2.001			
2.F.1.D Transport refrigeration	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Emissions (before recalculation) $CO_{2\text{-eq}}$, kt	0.077	0.166	0.269	0.507	0.996	1.532	2.240	2.270
Emissions (after recalculation) $CO_{2\text{-eq}}$, kt	0.199	0.372	0.468	0.902	1.815	2.590	3.588	2.774
Emission difference,%	159.863	123.46	73.793	78.09	82.219	69.025	60.195	22.213
2.F.1.D Transport refrigeration	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Emissions (before recalculation) $CO_{2\text{-eq}}$, kt	3.823	3.655	4.372	6.214	8.343	9.620	9.754	8.619
Emissions (after recalculation) $CO_{2\text{-eq}}$, kt	5.899	4.134	5.108	8.592	11.813	12.239	11.208	7.320
Emission difference,%	54.296	13.113	16.835	38.26	41.590	27.228	14.916	-15.07

4.25.1.1.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.25.1.2. Stationary Air Conditioning

4.25.1.2.1 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 2016 in Ukraine are summarized in Table 4.29.

Table 4.29 Basic data on results of GHG inventory in production and operation of stationary air-conditioning equipment in Ukraine in 2016

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	335.19	-	251.606	36.880	27.691	16.039	0.002
HFC balance in operated equipment, t	1350.35	55.11	1238.82	171.763	174.777	76.113	7.183
Category characteristics and estimated factors							
Key category	No	No	No	No	No	No	No
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	67.518	2.755	61.94	25.765	26.217	11.417	1.077
from liquidation of the equipment, t	0.113	0.0056	0.113	-	-	-	-
Emissions of HFCs in the air conditioning category, total, t	67.630	2.761	62.054	25.765	26.217	11.417	1.077
Global Warming Potential (GWP), t CO_{2-eq}/t	675	1430	3500	675	3500	1430	4470
GHG emissions, kt of CO_{2-eq}	45.651	3.948	217.190	17.391	91.758	16.326	4.816
Change in emissions compared to the previous year,%	26.578	197.472	19.43	8.24	1.002	7.964	-14.97
Emissions, % of the total direct action GHG emissions in the sector	0.46			0.22			
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.*

4.25.1.2.2 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 the national statistics of Ukraine on import and export of air-conditioning equipment in 2016 and from companies producing conditioning equipment. For 2014 - 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] 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.

The sharp increase in the use of HFC-134a in 2016 explains by an increase in imports of HFC-containing equipment mainly containing HFC-134a, in accordance with the data of the Fiscal Service of Ukraine

4.25.1.2.3. 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 2016 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 2016 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 2016 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.

4.25.1.2.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.25.1.2.5. Category-specific recalculations

In 2016, recalculation of HFC-134a emissions was conducted due to correction of the data on the amount of HFCs in imported equipment in accordance with data obtained from enterprises for 2015 (see Table 4.30).

Table 4.30 Recalculation of emissions from HFC use in refrigeration equipment for 2015

2.F.1.F Stationary Air Conditioning	**2015**
Emissions (before recalculation) $CO_{2\text{-}eq}$, kt	346,772
Emissions (after recalculation) $CO_{2\text{-}eq}$, kt	346,986
Emission difference,%	0,062

4.25.1.2.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.25.1.3 Mobile Air-Conditioning

4.25.1.3.1 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 2016, 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 declined by 14% compared with the previous year. Manufacture of vehicles equipped with air-conditioning decreased sharply 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 2016 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 4.31 summarizes results of GHG inventory in production and operation of vehicle SACs in Ukraine.

Table 4.31 Basic data on results of GHG inventory in production and operation of vehicle SACs in Ukraine in 2016

Category code	**2.F.1.E**				
Category (type of equipment)	**Mobile Air Conditioning Systems**				
	for auto-motive 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	2.298	0.0045	0.00351	0.288	NA
HFC stock after the initial filling, t	2.286	0.00448	0.00349	0.287	NA
Amount of HFCs in exported SACs as parts of vehicles, t	0.006	0.000016	0.000017	0.00019	NA
Amount of HFCs in imported SACs as parts of vehicles, t	3.195	0.0015	0.0017	0.0034	NA
HFC stock in exported SACs as parts of vehicles, t	568.957	0.262	0.211	1.369	NA
Category characteristics and estimated factors					
Key category	No	No			No
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	0.000022	0.000018	0.0014	NA
at operation of the equipment, t	85.344	0.0393	0.0318	0.205	NA
at liquidation of the equipment, t	0.978	-	-	-	NA
Emissions of HFCs in category, total, t	85.344	0.0393	0.032	0.207	NA
Global Warming Potential (GWP), t CO_{2-eq} /t	1430	675	3500	1430	NA
GHG emissions, kt of CO_{2-eq}	123.457	0.027	0.111	0.296	NA
Change in emissions compared to the previous year, %	-13.21	-13.32	-13.19	8.304	NA
Emissions, % of the total direct action GHG emissions in the sector	0.21	0.00075			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

4.25.1.3.2 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 State Statistics Service 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. For 2014 - 2016, the analytical study, which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [20] 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.

4.25.1.3.3. 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 2016 were determined.

The uncertainty level of activity data in the SAC subcategory for the road transport in 2016 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 2016 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 2016 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%.

4.25.1.3.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.25.1.3.5. Category-specific recalculations

In accordance with provisional main findings identified by the ERT calculation of emissions from Mobile air conditioning systems in automotive vehicles for the period of 1998 – 1999 were made based on information on the import of cars in 1998 - 1999, obtained from the State Statistics Service of Ukraine[23] and using extrapolation methods. 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 State Statistics Service of Ukraine[23]. The estimations of the emissions are shown in CRF tables and Annex 3, Table A3.1.1.18. Also in 2016, recalculation of HFC-134a, HFC-32 and HFC-125a emissions was conducted due to correction of the data on the amount of HFCs in exported and imported equipment for railway transport in 2015 in accordance with data obtained from enterprises. Recalculation of HFC-134a was conducted due to allocation of the emissions from the end of the lifetime of HFCs equipment for automotive vehicles 2015 (see Table 4.32).

Table 4.32 Recalculation of emissions from HFC use in mobile air conditioners for 2015

2.F.1.3 Mobile air conditioners	2015
Emissions (before recalculation) CO_{2-eq}, kt	144.3280
Emissions (after recalculation) CO_{2-eq} , kt	144.3501
Emission difference,%	0.0153

4.25.1.3.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.25.2 Foam Blowing Agents (CRF category 2.F.2).

4.25.2.1 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 2016, hydrofluorocarbons HFC-134a, HFC-245fa, HFC-365mfc and HFC-227ea 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 2016 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 2016, 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 extruded polystyrene (XPS), in 2016 only 1 manufacturer 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 4.33 summarizes results of GHG inventory in production and use of foamed HFC-containing materials in 2016.

Table 4.33 Basic data on results of GHG inventory in production and use of foamed HFC-containing materials in 2016

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**
Activity data								
HFC amount used in production of foamed materials (products), t	0.0	11.19	0.0	33.148	0.0	0.0	8.967	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
HFC amount contained in imports of foamed materials (products), t	24.52	0.623	1	0.0	0.0	0.0	0.0	0.254
HFC stock as of the end of 2016, t	0.0	23.996	14.423	190.71	146.052	149.413	38.932	171.259
Category characteristics and estimated factors								
Key category	No	No	No	No	No	No	No	No
Detail level (Tier)	2a	2a	2a	2a	2a	2a	2a	2a
Method for determination of the emission factor	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
Emission factor from the stock,%	0.0	0.5	0.5	1.5	1.5	1.5	1.5	3.0
Average service life of the material (product) during operation, years	1	50	50	50	50	50	50	50
GHG emissions								
HFCs emissions								
in manufacture of foamed materials (products), t	0.0	1.399	0.0	8.287	0.0	0.0	2.241	0.0
in operation of foamed materials (products), t	24.52	0.12	0.0721	2.861	2.190	2.241	0.584	5.132
Emissions of HFCs in category, total, t	24.52	1.518	0.0721	11.148	2.190	2.241	2.825	5.132
Global Warming Potential (GWP), t $CO_{2\text{-eq}}$ /t	1430	1430	1030	1430	1030	794	3220	1430
GHG emissions, kt of $CO_{2\text{-eq}}$	35.061	2.171	0.0743	15.941	2.256	1.779	9.099	7.338
Change in emissions compared to the previous year (increase/decrease rate),%	25	22.304		19.885				-3

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
Emissions, % of the total direct action GHG emissions in the sector	0.06	0.0039		0.05				0.013
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

4.25.2.2. 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 analytical review of the foam market of Ukraine on production of foams in 2016.

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).

According to analytical review of the foam market of Ukraine a sharp increase in HFCs emissions from one-component polyurethane foams, panels and sandwich panels made of rigid polyurethane foams (RPUF) and rigid polyurethane foam (PUF insulation by spraying, pouring, injection) explaines by growth production and use of foamed HFC-containing materials in 2016.

4.25.2.3. 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 2016 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 2016 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%.

4.25.2.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use. An expert opinion from a group of experts of SE "Cherkasky NIITEKHIM" was obtained for this category.

4.25.2.5. Category-specific recalculations

In 2016, recalculation of HFC-365mfc emissions was conducted due to correction of the data on the amount of HFCs in stocks of foamed materials in 2015, in accordance with data obtained from enterprises (see Table 4.34).

Table 4.34 Recalculation of emissions from HFC use in mobile air conditioners for 2015

2.F.2 Foam Blowing Agents	**2015**
Emissions (before recalculation) CO_{2-eq}, kt	62.908
Emissions (after recalculation) CO_{2-eq} , kt	61.704
Emission difference,%	-1.915

4.25.2.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.25.3 Fire protection (CRF category 2.F.3)

4.25.3.1 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 2016 only HFC-125 and HFC-227ea were applied.

Manufacture of fire-fighting equipment using HFCs as a fire extinguishing agent in 2016 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 4.35 summarizes results of GHG emission inventory in production and operation of gas extinguishing systems using HFCs in 2016.

Table 4.35. Basic data on results of GHG inventory in production and operation of gas fire fighting modules (GFFMs) in 2016

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	18.123	6.575
Amount of HFC in exported equipment, t	-	-
Amount of HFC in imported equipment, t	-	9.292
HFC stock in the operated equipment as of the end of 2015, t	126.277	104.323
HFC stock in the operated equipment as of the end of 2016, t	139.349	116.018
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	5.574	4.640
at liquidation of the equipment, t	0.0	0.0
Emissions of HFCs in category, total, t	5.574	4.640
Global Warming Potential (GWP), t CO_{2-eq} /t	3500	3220
GHG emissions, kt of CO_{2-eq}	19.509	14.943
Change in emissions compared to the previous year (increase/decrease rate),%	10.352	11.209
Emissions, % of the total direct action GHG emissions in the sector	0.033	0.026
Uncertainty level estimation		
Uncertainty of activity data, %	16.70	
Uncertainty of the emission factor, %	not performed	
Uncertainty of the emission estimation, %	16.70	

4.25.3.2 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 2016 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;
- 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).

4.25.3.3 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 2016.

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 2016 was 16.70%.

4.25.3.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.25.3.5 Category-specific recalculations

In 2016, recalculation of HFC-227ea and HFC-125 emissions were conducted due to availability of more accurate data on the amount of HFCs in imported and used in equipment production of gas fire fighting modules (GFFMs) in 2011 – 2015, in accordance with data obtained from enterprises (see Table 4.36).

Table 4.36 Recalculation of emissions from HFC use in gas fire fighting modules (GFFMs) in 2011 - 2015

2.F.3 Fire protection	**2011**	**2012**	**2013**	**2014**	**2015**
Emissions (before recalculation) $CO_{2\text{-eq}}$, kt	17.894	19.938	24.558	27.889	30.069
Emissions (after recalculation) $CO_{2\text{-eq}}$, kt	19.058	21.056	25.631	28.996	31.116
Emission difference,%	6.503	5.603	4.367	3.971	3.482

4.25.3.6 Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.25.4 Aerosols (CRF category 2.F.4)

4.25.4.1 Category description

In 2016 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 2016, 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 2016, 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 4.37 summarizes results of GHG inventory in production and use of HFC-containing aerosols in 2016.

Table 4.37 Basic data on results of GHG inventory in production and use of HFC-containing aerosols in 2016

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	21.467	-	-
HFC amount contained in exports of aerosols, t	3.353	-	-
HFC amount contained in aerosol supplies for the domestic market, t	-	-	-
HFC amount contained in imports of aerosols, t	54.241	-	-
Net consumption of HFCs contained in aerosols, t	72.356	-	-
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	66.282	-	-
Emissions of HFCs in category, total, t	66.282	-	-
Global Warming Potential (GWP), t CO_{2-eq} /t (SAR)	1430	-	-
GHG emissions, kt of CO_{2-eq}	94.783	-	-
Change in emissions compared to the previous year (increase/decrease rate),%	24.23	-	-
Emissions, % of the total direct action GHG emissions in the sector	0.163	-	-
Uncertainty estimation			
Uncertainty of activity data, %	6.70	Not determined	
Uncertainty of the emission factor, %	5.39		
Uncertainty of the emission estimation, %	8.60		

4.25.4.2 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 2016, the growth dynamics in HFC emissions from the category of aerosol products for medical purposes in Ukraine ceased, and increased compared to the previous year. This trend is likely to be situational and is due, in addition to the purchasing power, to the administration of the domestic pharmaceutical market.

4.25.4.3. 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 2016 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 2016 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 2016, 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%.

4.25.4.4. Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in HFC use.

4.25.4.5. Category-specific recalculations

In 2016, recalculation of HFC-134a emissions were conducted due to availability of more accurate data on the amount of HFCs in imported and used in equipment production of aerosols in 2015, in accordance with data obtained from enterprises (see Table 4.38).

Table 4.38 Recalculation of emissions from HFC use in aerosols in 2015

2.F.4 Aerosols	**2015**
Emissions (before recalculation) $CO_{2\text{-eq}}$, kt	61.979
Emissions (after recalculation) $CO_{2\text{-eq}}$, kt	76.298
Emission difference,%	23.103

4.25.4.6. Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.25.5 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 2016. Analysis of the statistics for 2016 confirmed that solvents were not imported to Ukraine. Therefore, estimation of GHG emissions in this category was not performed.

4.25.6 Other Applications of Substitutes for Ozone-Depleting Substances

As a result of the analysis of imports and domestic sales of HFCs and sulfur hexafluoride in 2016, no data on use of these gases used in other industries were obtained..

Therefore, estimation of GHG emissions in this category was not performed.

4.26 Other Product Manufacture and Use (CRF category 2.G)

4.26.1 Electrical Equipment (2.G.1 CRF)

4.26.1.1 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 2016

Category code	**2.G.1 CRF**
Category (type of equipment)	**Gas-insulated equipment**
Gas	**Sulfur hexafluoride**
Activity data	
The amount of SF_6 imported into Ukraine in 2016, t	8.65
Number SF_6 used in production of gas-insulated equipment (filling stage), t	0.153
Amount of SF_6 in exported gas-insulated equipment, t	-
Amount of SF_6 in imported gas-insulated equipment, t	8.483
Amount of SF_6 in installed gas-insulated equipment (nameplate capacity of new equipment put into operation in 2016), t	42.283
Amount of SF_6 in operated gas-insulated equipment (nameplate capacity of operated equipment as of the end of 2015), t	169.242
Amount of SF_6 in operated gas-insulated equipment (nameplate capacity of operated equipment as of the end of 2016), t	210.679
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	0.00076
at installation (assembly) of gas-insulated equipment, t	0.00334
at operation of gas-insulated equipment, t	1.053
SF_6 emissions in the gas-insulated equipment category, total, t	1.057
Global Warming Potential (GWP), t CO_2e/t	22800
GHG emissions, thousand tons of CO_2e	24.111
Growth/reductionof emissions compared to the previous year (+/-),%	24.3
Emissions, % of the total direct action GHG emissions in the sector	0.042
Uncertainty level estimation	
Uncertainty of activity data, %	34.104
Uncertainty of the emission factor, %	18.0
Uncertainty of the emission estimation, %	38.56

4.26.1.2 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 2016 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 2016 in accordance with data obtained from State Fiscal Service of Ukraine. Data on actual volumes of sulfur hexafluoride used in production of gas-insulated equipment in 2016 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 [20] for adjustment of volumes of sulfur hexafluoride in 2014 - 2016.

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 2016, the average factor of 0.5% was applied.

4.26.1.3 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 2016, 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 2016 was 18%.

The overall uncertainty of sulfur hexafluoride emission estimation was 38.56% in 2016.

4.26.1.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of GHG emissions in SF_6 use.

4.26.1.5 Category-specific recalculations

In 2016, recalculation of SF_6 emissions was conducted in this category for 2014 - 2015 due to availability of more accurate data on the amount of SF_6 in operated gas-insulated equipment, in accordance with data obtained from enterprises (see Table 4.40).

Table 4.40 Recalculation SF6 emissions in electrical equipment in 2014 – 2015

2.G.1 Electrical equipment	**2014**	**2015**
Emissions (before recalculation) $CO_{2\text{-eq}}$, kt	16.485	18.939
Emissions (after recalculation) $CO_{2\text{-eq}}$, kt	16.726	19.397
Emission difference,%	1.457	2.418

4.26.1.6 Category-specific planned improvements

See in Annex A8.2 Improvement plan for NIR.

4.26.2 N_2O from Product Uses (2.G.3 CRF)

4.26.2.1 Category description

In this category, nitrous oxide emissions from its use for medical purposes (anesthesia) are estimated. Nitrous oxide emissions in 2016 amounted to 0.487 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.

4.26.2.2 Methodological issues

In this inventory, for the first time in the time series of 1990-2016, 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" [19], 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 1990-2015 were analyzed and systematized in the expert opinion[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 [20] for adjustment of number of surgical operations in 2014 - 2016. The detailed information is presented in Table 4.41 below. In general, the number of surgical operations has gradually increased from 4280.605 thousand in 1990 and reached 4300.679 thousand in 2015, in 2016 – 4282.221 thousand. This trend from 1990 to 2016 is due to a number of reasons: an increase in the general morbidity rate in the population, 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.

The share of inhalation surgeries (IA). The value of the IA factor for the time-series of 1990-2016 was calculated in the expert opinion[1], according to which this factor gradually increased from 0.15 in 1990 and reached the value of 0.51 in 2016, 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 1990-2016 was calculated in the expert opinion[1], according to which this factor gradually increased from 0.100 in 1990 and reached the value of 0.279 in 2016, 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 [19], 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.

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[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.

Table 4.41. Use of nitrous oxide for medical purposes in Ukraine, 1990-2016

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	4282.221	0.51	0.279

4.26.2.3 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**

4.26.2.4 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;

4.26.2.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.26.2.6 Category-specific planned improvements

In this category, no improvements are planned.

4.27 Pulp and Paper Production (CRF category 2.H.1)

4.27.1 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 4.43 shows the basic data on the results of GHG inventory in paper production.

Table 4.43. The basic data on the results of GHG inventory in paper and pulp production in 2016

Category code	**2.H.1**			
Gases	NO_x	CO	NMVOC	SO_2
Emissions from production, kt	0.638	3.511	1.277	1.277
Change in emissions compared to the previous year,%	-8.86			
Change in emissions compared to the baseline year,%	34.89			
Emissions, % of emissions in the sector	3.2	9.65	1.15	2.22
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

4.27.2 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 State Statistic Service of Ukraine [2]. The default GHG and SO_2 emission factors were used.

4.27.3 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.

4.27.4 Category-specific QA/QC procedures

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

4.27.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.27.6 Category-specific planned improvements

In this category, no improvements are planned.

4.28 Food and Beverages Industry (CRF category 2.H.2)

4.28.1 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 4.44 presents activity data, emission and NMVOC emission factors at production of food and beverages in Ukraine in 2016.

Table 4.44. NMVOC emissions in production of food and beverages in 2016

Category code	**2.H.2**
Food Production, kt	11662.587
Beverage Production, 10^3 hl	20618.59
Gas	NMVOC
Emissions from products, kt	40.930
Emissions from beverages, kt	14.192
Total emissions, thousand tons	55.123
Change in emissions compared to the previous year,%	8.56
Change in emissions compared to the baseline year,%	-60.50
Emissions, % of emissions in the sector	44.85
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 A3.1.1.19, Annex 3.1.1.

4.28.2 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 State Statistics Service of Ukraine [2].

4.28.3 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.

4.28.4 Category-specific QA/QC procedures

General QA/QC procedures were applied for estimation of NMVOC emissions at food and beverage production.

4.28.5 Category-specific recalculations

In this category, no emission recalculations were made.

4.28.6 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 are accounted for 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 were 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	*2015*	*2016*	*by 1990*	*by 2015*
3.A Enteric Fermentation	45 924.87	10 970.24	10 752.01	-76.59	-1.99
3.B Manure Management	7 308.44	2 224.99	2 126.43	-70.90	-4.43
3.C Rice Cultivation	216.43	86.70	89.07	-58.85	2.73
3.D Agricultural Soils	35 709.95	25 979.33	28 876.25	-19.14	11.15
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	169.83	140.09	-94.60	-17.51
3.H Urea Application	270.14	372.50	457.62	69.40	22.85
Total for the sector	**92 021.91**	**39 803.60**	**42 441.46**	**-53.88**	**6.63**

** – the emissions are not estimated.*
*** – field burning of crop residues is prohibited by the Ukrainian legislation.*

The total GHG emissions in the sector have decreased by 53.88% compared to the base year and increased by 6.63% in comparison with previous 2015 (Table 5.1).

The highest emissions in the agricultural sector of Ukraine in 2016 were observed in 3.D Agricultural Soils and 3.A Enteric Fermentation categories, which make up 68.04 and 25.33% (Fig. 5.1). The next largest category is 3.B Manure Management, which accounts for 5.01% of the emissions. Contribution of the other categories is negligible and accounts for only 1.62%.

The key gases in the sector are methane and nitrous oxide (Fig. 5.2), which accounted for 54.21 and 42.68% in 1990, and 28.04 and 70.56% of the emissions in 2016, respectively.

The reduction in emissions of GHG over the period of 1990-2016 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 growth in emissions 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 was characterized by rapid changes in sales prices for live animals, feed grain, and other fodder.

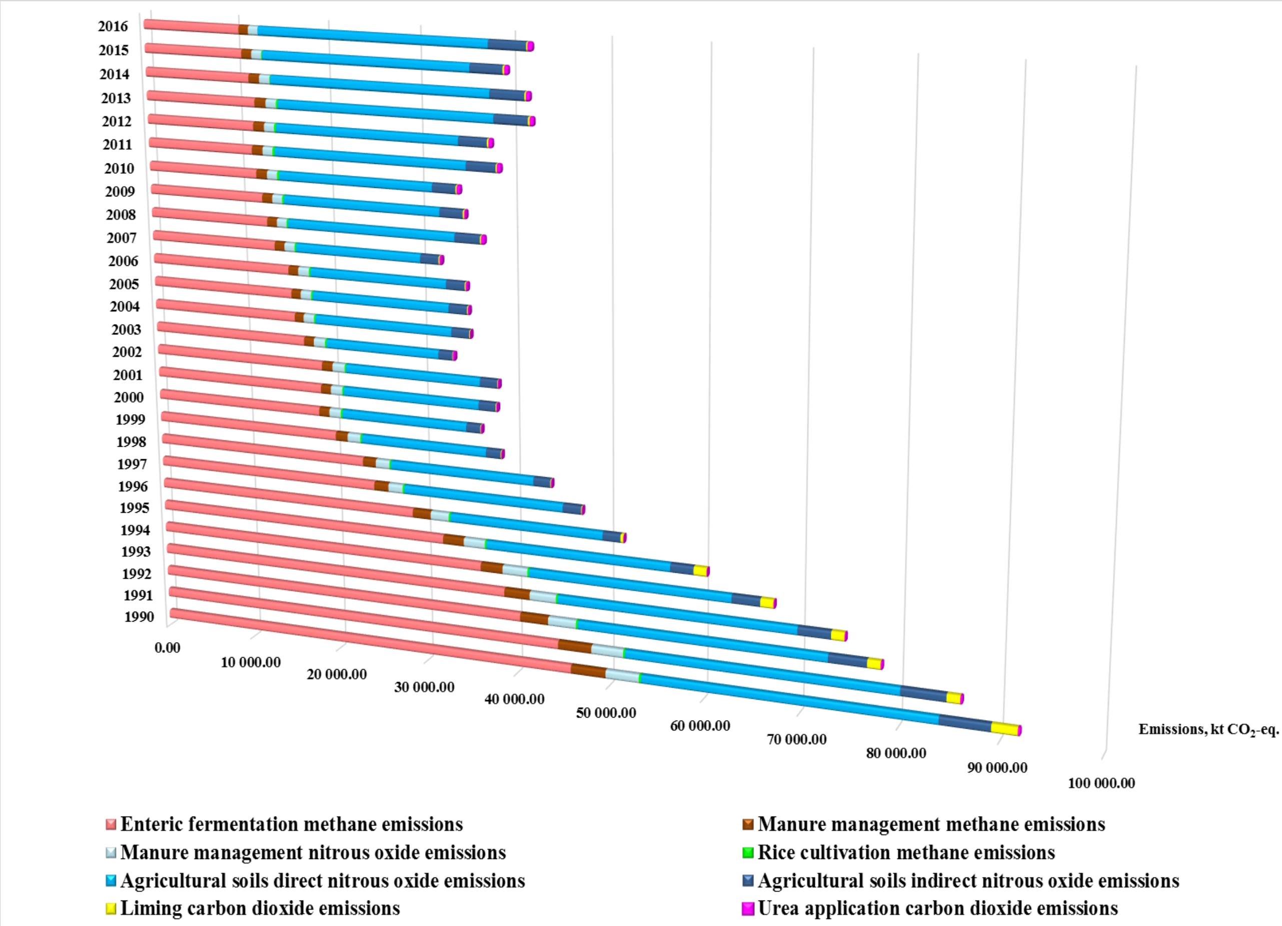


Fig. 5.1. GHG emissions by categories of the Agriculture sector, kt CO_2-eq.

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 2008, 2010-2014 there was an increase in the standardly introduced nitrogen fertilizers.

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 2016, the corresponding proportion of manure in liquid systems was approximately 5.2%, 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 1990-2016 sharply reduced. At the same time, methane emissions in the category in question in the reporting period decreased by 71.8%.

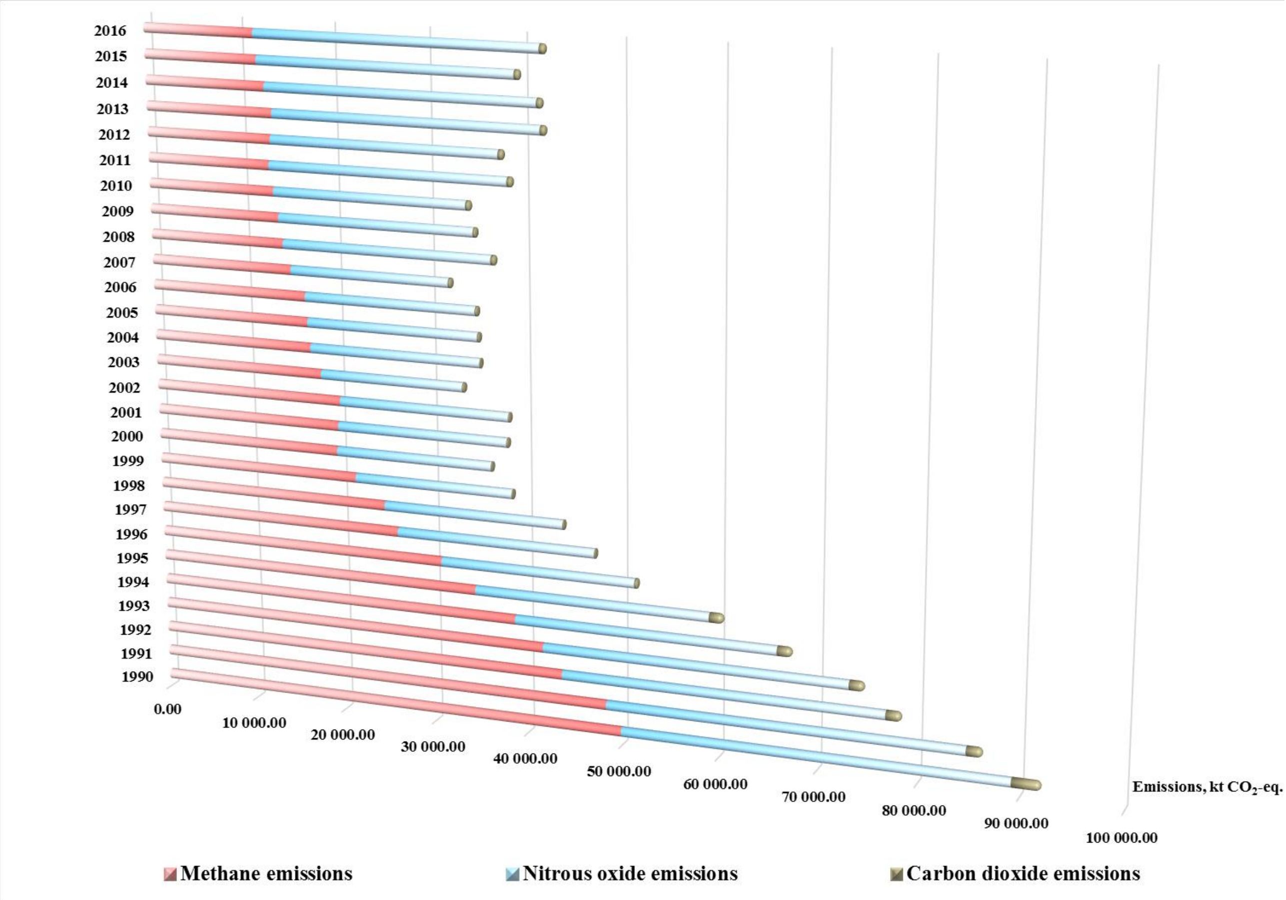


Fig. 5.2. The ratio of direct GHG emissions in the Agriculture sector, kt CO_2-eq.

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). 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 1990	Emissions, kt 2016	Trend, %
3.A.1 Cattle	T3	CS	CH_4	Level/Trend	1 726.00	398.65	-76.90
3.A.2 Sheep	T2	CS			60.91	8.12	-86.67
3.A.3 Swine	T1	D			29.53	10.68	-63.82
3.A.4 Other animals	T1	D			20.55	12.62	-38.58

Methane is one of major GHG. In agricultural sector of Ukraine, most of its emissions come from Enteric Fermentation in ruminants, in particular – cattle.

The digestive process products CH_4 and its emission primarily depends on:

– the type of animals (Table 5.3, Annex 3.2.1), their number and size;
– the type of the digestive system of the animals;
– the type and amount of fodder consumed.

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

Animal species	Data source*	Reporting form	Note**
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

** – SSSU – State Statistical Service of Ukraine; FAO – United Nation Food and Agriculture Organization;*
*** – 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 A3.2.8.3). Cattle EF fluctuations mainly caused by changes of fodder consumption, and sheep EF fluctuations caused by changes of several data (live weight, milk yield, wool production and other).

Methane emissions from enteric fermentation in the base, several intermediate and last years are reported in Table 5.4.

Table 5.4. Methane emissions from enteric fermentation, kt CH_4

CRF type/group of animals		1990	1995	2000	2005	2010	2015	2016
3A Enteric Fermentation, total, incl.:		1 836.99	1 282.53	738.74	628.78	487.68	438.81	430.08
3A.1	Mature dairy cattle	915.88	734.37	473.17	424.30	324.60	292.17	284.48
	Mature non-dairy cattle	140.15	115.74	54.18	30.91	19.59	15.41	14.30
	Growing cattle	669.97	359.11	168.88	137.58	106.86	98.68	99.87
3A.2	Sheep	60.91	30.59	8.26	7.44	10.01	8.51	8.12
3A.3	Swine	29.53	20.32	13.29	10.14	11.65	11.18	10.68
3A.4	Fur-bearing animals	0.14	0.12	0.05	0.07	0.08	0.07	0.07
	Rabbits	4.27	4.60	3.91	3.73	3.84	3.80	3.75
	Camels	0.03	0.03	0.03	0.03	0.04	0.04	0.04
	Mules and asses	0.19	0.01	0.01	0.12	0.12	0.12	0.12
	Buffaloes	0.05	0.04	0.03	0.02	0.004	0.003	0.003
	Horses	13.43	13.43	12.59	10.31	7.72	5.68	5.46
	Goats	2.45	4.18	4.34	4.13	3.17	3.14	3.18

Analysis of Table 5.4 leads to the conclusion that the highest emissions in this category are produced by cattle enteric fermentation, providing for over 90% 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).

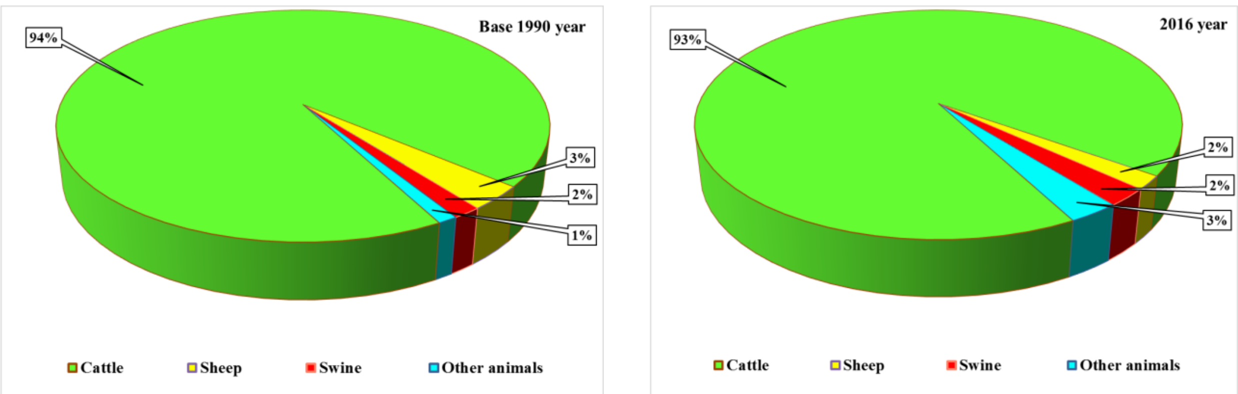


Fig. 5.3. Contribution of animal groups into the total methane emissions from enteric fermentation, %

5.2.2 Methodological issues

5.2.2.1. The methodology for CH_4 emissions estimation from cattle enteric fermentation

Calculation of methane emissions from cattle enteric fermentation based on Tier 3 methodology [3]. To harmonize the methodology with the main principles of IPCC, assessment of the quality and completeness of the SSSU data an additional verification of the Tier 3 methodology for cattle enteric fermentation estimation [3] has been started. Its results reporting planned in the next NIR submission.

Cattle livestock number (Annex 3.2.1.3, Tables A3.2.1.3.1 and A3.2.1.3.2) and country specific EF for each sex-age cattle group (Annex 3.2.8, Table A3.2.8.1) used for methane emissions estimation according to this methodology. GHG emissions from cattle enteric fermentation calculated in line with Equation 10.19 of 2006 IPCC Guidelines [1].

SSSU database and analytical study methodological approaches [2] used for cattle livestock estimation (Table 5.3, Annex 3.2.1).

Country specific EF for each sex-age cattle group calculated in line with Equation 10.21 of 2006 IPCC Guidelines [1] and reported in Table A3.2.8.1 of Annex 3.2.8.

Cattle methane conversion factor Y_m source is a Table 10.12 of 2006 IPCC Guidelines [1]. Its value assumed as 6.5%.

As shown in Equation 5.1, GE requirement is derived based on the amount of gross energy in 1 kg of fodders, values of parts by weight of fodders, the proportion of the cattle sex-age groups, fodder consumption and cattle livestock.

$$GE = \frac{\left[F_r \sum_n \sum_j (g_{rj} \times \alpha_{jn}) f_{nq} + F_g \sum_n \sum_k (g_{gk} \times \beta_{kn}) f_{nq} + F_s \sum_n \sum_l (g_{sl} \times \delta_{iln}) f_{nq} + F_c \sum_n \sum_m (g_{cm} \times \varepsilon_{mn}) f_{nq}\right]}{N \times 365}, \quad (5.1)$$

where:

GE – gross energy intake, MJ / head per day (Annex 3.2.2, Table A3.2.2.11);

j, k, l, m – indexes of fodder type (concentrated, succulent, coarse and other fodders);

n – the index of the natural zone (Polissia, Wooded Steppe and Steppe);

q – the index of the farm category (agricultural enterprises and households);

g_{rj}, g_{gk}, g_{sl}, g_{cm} – the amount of gross energy in 1 kg of *j, k, l,* and *m* fodder type, MJ / kg;

α_{jn}, β_{kn}, δ_{ln}, ε_{mn} – values of parts by weight of *j, k, l,* and *m* fodder type in the natural zone *n*, relative units;

f_{nq} – the proportion of the livestock of cows and other cattle in *q* category farms within the natural zone *n*, relative units;

F_r, F_g, F_s, F_c – the amount of concentrated, succulent, coarse and other fodders in each cattle group, kg / yr;

N – the number of head of cattle livestock, head (Annex 3.2.1.3, Tables A3.2.1.3.1 and A3.2.1.3.2).

Four types of fodders are determinate (concentrated, succulent, coarse and other fodders), which differ in GE value (Annex 3.2.2, Table A3.2.2.1). Cereal forage, bran, mixed fodders, flour, press cake, grist, vitamin-grassy flour and waste from bakery, mill, etc. are the part of concentrated fodders. Succulent fodders contain a silage, potato, root crops, vegetables, melon crops, beet pulp, pomace, and other waste from food industry. Coarse fodders – hay, hay flour, straw, chaff, corn stem, stems of perennial grasses, dehydrated green fodders, sugar beet tops, other crop waste as a flour, chaff, granules and briquettes. Milk, whey, meat and bone meal, food waste, pastures, etc. included in other fodders.

Their consumption are fluctuated for the cattle sex-age groups in agrienterprises and households during the time series period (fodder consumption AD from SSSU are reported in Annex 3.2.2,

Table A3.2.2.2). In accordance with statistical data, there is a fluctuation in the cattle ration structure (Annex 3.2.2, Table A3.2.2.3). Generally, there is an increase in consumption of fodders with highest GE observed in all kinds of enterprises. Economic situation in Ukraine and practice of cattle feeding at agrienterprises and households determinates the fluctuation of fodder consumption. The collapse of the Soviet Union caused a decreasing of consumed fodders amount and deterioration of their quality. Economic growth and the change in the basic principles of animal breeding led to a positive dynamics of fodder consumption.

To show the differences in the structure of fodder rations, the amount of fodder consumed, and other indicators, the cattle herd was divided into animals in agricultural enterprises and households, as well as by sex-age groups (Annex 3.2.1.1, Tables A3.2.1.1.1 and A3.2.1.1.2).

The source of data on consumption of concentrated, succulent, coarse and other fodders for cattle in agricultural enterprises were SSSU forms (where these data calculated in accordance with SSSU methodology [4-5]) and analytical study, which includes different methodological approaches [2]. For the period of 1990-2004, annual form No.24-fodder "Balance of fodders" served as a source of information. The information database on fodder consumption in 2005 is annual form No.24 "The status of livestock in Ukraine", the section "Balance of fodders at agricultural enterprises in Ukraine" and the table "Fodder consumption", where the calculation is performed according to the "Guidelines for estimation of fodder consumption for livestock and poultry in all categories of farms" [4]. From 2014, fodder consumption data at agrienterprises corrected according to analytical study [2]. Livestock by the sex-age groups and fodder consumption per head by the fodder types for each cattle group used for this correction. Updated SSSU methodology [5] approved for estimation data about fodder consumption at agrienterprises.

Data on fodder consumption in households are estimated by the SSSU (where these data calculated in accordance with SSSU methodology [4-5]) and analytical study [2, 4-5]. Until 2001, the data source for the estimations were: propagated data on fodder consumption per head of cattle from household budget sample surveys; form No.24-fodders "Balance of fodders"; the results of accounting, livestock and poultry census in farms and in households. After introduction in 2001 of the sample survey of agricultural activities in rural areas, estimations on fodder consumption in households were conducted based on form No. 01-SHN, from No. 02-SHN, form No.24-fodders "Balance of fodders", and standards of livestock feeding [6-9]. Since 2005, estimation of fodder consumption in households has been conducted at the national level in accordance with the "Guidelines for estimation of fodder consumption for livestock and poultry in all categories of farms" [4]. From 2014, fodder consumption data at households corrected according to analytical study [2]. Updated SSSU methodology [5] approved for estimation data about fodder consumption at households. There are same methodological approaches used for fodders consumption data correction at agrienterprises and households.

Due to the fact that statistics on fodder consumption at agricultural enterprises and households cannot be directly used in the inventory process, they were brought to the format suitable for calculating methane emissions from cattle enteric fermentation (Annex 3.2.2, Table A3.2.2.2) using the following algorithm:

– the total amount of fodder consumed in all types of feed units is calculated for a specific sex-age group of cattle used in the GHG inventory;

– for a specific sex-age group of cattle, the amount of fodder consumed in feed units is defined and broken down into concentrated, succulent, coarse and other ones;

– with coefficients of fodders energy content, fodder consumption is converted from feed units into natural (kg) ones [7-13].

In primary sources, statistical data on fodder consumption for all types of farms are presented for the two cattle groups – "Cows (including bulls of dairy herd)" and "Other cattle (without cows and bulls of dairy herd)". Calculation of the amount of fodder consumed in the context of sex-age groups was made based on the standard indicators of fodder consumption in feed units per head per day [7-10], and to derive the total feed flow rate, they were multiplied by the number of animals in the corresponding group. Thus, for the conditions of Ukraine feed flow ratios were determined in the context of sex-age groups of cattle, which, basically, vary depending on the breed composition, average body weight, growth rate, load rate (for bulls), and productive performance.

The cattle groups "Cows" and "Other cattle" (mostly youngsters up to 1 year) make up a significant proportion of the total cattle population. In order to increase accuracy of the estimations and to ensure data completeness, the amount of consumed fodder for dairy cows and for other cattle herd were estimated, according to the statistics, not based on standards but as the difference between the total fodder consumption and fodder consumption for feeding the rest of the sex-age groups.

The statistical sources for households offer data on the total amount of fodder consumed in all types of feed units, and also separately focus on concentrated fodder. Amounts of consumed succulent and other fodder for each sex-age group were taken based on normative data on the structure of fodder for cattle at households defined based on statistical data [4]. Given the partial interchangeability of concentrates and coarse fodder in the cattle feeding practice, to ensure completeness of the data the ratio of coarse fodder in the total ration was calculated as the difference between the total fodder consumption (100%) and the shares of concentrates, succulent and other fodder (Annex 3.2.2, Table A3.2.2.3).

The chemical composition, forage nutritive value, and the ratio of plant-origin products in the composition of concentrated, succulent, coarse and other fodders are different depending on the climatic zones of the country, sex-age groups of the animals, the degree of the load (for bulls), and cattle productive performance. As a consequence, the amount of GE in fodder rations for the corresponding average load of bulls and productivity of dairy cattle of 5 and 10 kg/head per day was calculated in the context of sex-age groups, as well as the climatic zones of Ukraine (Annex 3.2.2, Table A3.2.2.1), such as: Polissia, Wooded Steppe and Steppe [6]. Findings of national studies [7-13] were used as a source database to estimate the GE.

The fodder balance of all zones is dominated by corn silage, grain, and green mass, while in the Wooded Steppe, additionally, – beet pulp. Given the feeding conditions of the Polissia, Wooded Steppe and Steppe, the calculations are based on three types of cattle feeding (silage/root, silage/pulp, and silage) and cattle for fattening (combined, pulp, and silage feeding).

To calculate the GE content in 1 kg of crop products that are fodder ingredients, Equation 5.2 was used, which provides for multiplying the amount of nutrients in the fodder (protein, fats, and carbohydrates) by the corresponding energy equivalents [14]:

$$GE = 0{,}0239 \times CP + 0{,}0398 \times CF + 0{,}0201 \times CC + 0{,}017 \times ES, \quad (5.2)$$

where:
GE – amount of gross energy in 1 kg of feed, MJ;
CP – content of crude protein in the fodder, g;
CF – content of crude fat in the fodder, g;
CC – content of crude carbohydrates in the fodder, g;
ES – content of nitrogen-free extractives in the fodder, g.

The average values of the energy content of fodders in the diet of a particular group of cattle in the corresponding climatic zone were derived on the basis of the ratio of the relevant crop products in the feed balance of concentrated, succulent, coarse and other fodders [6, 9-10]. To calculate the values of GE in 1 kg of fodders in the context of gender and age groups at the national level, they were averaged by natural zones based on the share of the livestock of cows and other cattle in agricultural enterprises and in households. The average data by fodders and natural-climatic zones on the GE in 1 kg of concentrated, succulent, coarse and other fodders were then multiplied by the corresponding fodder flow rate to derive the total amount of energy in the diet of a particular sex-age group of cattle.

According to applied methodology, the milk yield of dairy cattle and live weight of all cattle groups are not used for GHG emissions calculation.

5.2.2.2. The methodology for CH_4 emissions estimation from sheep enteric fermentation

Tier 2 was used for methane emissions from sheep enteric fermentation calculation [1]. According to them, to estimate methane emissions, it is necessary to determine:

– number of sheep (Annex 3.2.1.3, Table A3.2.1.3.1);
– the amount of GE intake;
– a share of GE that is converted into methane.

Estimation of methane emissions from sheep enteric fermentation was carried out according to equation 10.19 of 2006 IPCC Guidelines [1].

Sheep EF was derived in accordance with equation 10.21 [1].

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);
– net energy for animal activity (equation 10.5);
– net energy for lactation (equation 10.9);
– net energy required for pregnancy (equation 10.13);
– ratio of net energy available in a diet for maintenance to digestible energy consumed (equation 10.14);
– net energy needed for growth (equation 10.7);
– net energy required for production of wool during a year (equation 10.12);
– ratio of net energy available for growth in a diet to digestible energy consumed (equation 10.15);
– digestible energy expressed as a percentage of GE.

For the purposes of the inventory, average values of live weight of ewes and rams were used [15-16], estimated based on the average live weight of sheep by breeds and breed types, their breed composition structure (Annex 3.2.2, Table A3.2.2.6 – A3.2.2.9).

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 [15-16].

Information about the method of sheep feeding was obtained based on an expert opinion of the National University of Life and Environmental Sciences of Ukraine.

Maintenance of sheep is 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 in dry, 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, are not grazed. The pasture sheep management system is not practiced in Ukraine due to the high rate of land plowing [17].

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 [17]. The lactation period of sheep in the conditions of Ukraine is on average 4 months. According to the SSSU, the milking herd of ewes is found in the six key regions: Vinnytska, Ivano-Frankivska, Odesska, Chernivetska Oblast, and the Autonomous Republic of Crimea.

To estimate the rate of sheep milk production (Annex 3.2.2, Table A3.2.2.6), 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 was 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 [16-17]). The energy value of sheep milk was taken in accordance with [23] as equal to 4.75MJ/kg.

There are no statistics in the country on the proportion of sheep who 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), so the assumption was made that all the ewes during the year are pregnant, and the coefficient corresponding to the average number of lambs born in a year was defined based on Table A3.2.2.6 (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 judgement from The National Academy of Agrarian Sciences of Ukraine (№20009/10-17 on 04 Aug 2017).

The source of wool production AD (Annex 3.2.2, Table A3.2.2.6) was the statistical yearbook [19].

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%) [15], the weighted average was calculated, which corresponds to the mark 0.0483 rel. units.

The results of calculation of national methane EF from sheep enteric fermentation by sex-age groups are reported in Table A3.2.8.3 (Annex 3.2.8).

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 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 are reported in Table A3.2.8.4 (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 are 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 [17] 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 4.4 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 [17]. 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 estimation was carried out with Tier 1 method in accordance with the methodology set out in 2006 IPCC Guidelines [1].

The uncertainty of emission estimation in category 3.A Enteric Fermentation is determined by uncertainties of AD and EF. Furthermore, for cattle and sheep the EF uncertainty was also caused by accuracy of the GE values for ration fodders, and by the methane conversion coefficient. Uncertainty indicators the statistical data set of the population of animals by type and sex-age groups in the public and private sectors, fodder consumption for livestock feeding, the amount of wool produced by sheep are taken at the level of 6%. According to the expert opinion, the data on feeding norms for cattle by sex-age groups correspond to the degree of accuracy of statistics.

The ranges and sources of uncertainty of input data used in calculation of national EF from cattle and sheep enteric fermentation are reported in Table 5.5.

Table 5.5. The uncertainty of input data used in calculation of national emission factors from cattle and sheep enteric fermentation, %

Indicator	Measurement unit	Uncertainty	Source
Cattle			
Norms of the required amount of fodder	f.u./head per day	5	Expert opinion
Statistical data on fodder consumption (concentrated, coarse, succulent, and other) for livestock	t.f.u.	6	Expert opinion based on SSSU data
Weighted average rates of energy nutritionally of concentrated fodders	f.u.	1-10	Factor range depending on the natural zone, according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average rates of energy nutritionally of coarse fodders	f.u.	2-16	Factor range depending on the natural zone, according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average rates of energy nutritionally of succulent fodders	f.u.	8-36	Factor range depending on the natural zone, according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average rates of energy nutritionally of other fodders	f.u.	3-4	Factor range depending on the natural zone, according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average amount of gross energy in 1 kg of concentrated fodders	MJ	1-9	The range of gross energy values per 1 kg of fodders depending on the natural zone, calculated based on the fodder chemical composition according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average amount of gross energy in 1 kg of coarse fodders	MJ	1-2	The range of gross energy values per 1 kg of fodders depending on the natural zone, calculated based on the fodder chemical composition according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average amount of gross energy in 1 kg of succulent fodders	MJ	3-34	The range of gross energy values per 1 kg of fodders depending on the natural zone, calculated based on the fodder chemical composition according to data of M. Karpus et al., 1993, 1994, and 1995.
Weighted average amount of gross energy in 1 kg of other fodders	MJ	7	The range of gross energy values per 1 kg of fodders depending on the natural zone, calculated based on the fodder chemical composition according to data of M. Karpus et al., 1993, 1994, and 1995.
Methane conversion factor	rel. u	8	IPCC Guidelines for National Greenhouse Gas Inventories [1]
Sheep			
Statistical data on livestock, sheep milk and wool production	kg/head per day	6	Expert opinion based on SSSU data
Average live weight	kg	1-35	Range of average body weight values depending on the breed and age and gender indicators, according to data of A. Vertiychuk, 2004 .; V. Iovenko et al., 2006; M. Shtompel et al., 2005; V. Sokolov et al., 2004; VNTP-APK-03.05, 2005.
Live weight at weaning	kg	4-7	Range of data based on VNTP-APK-03.05, 2005.
Live weight at the age of 1 year or at slaughter	kg	10-18	Range of data based on VNTP-APK-03.05, 2005.
Amount of digestible energy (percentage of gross energy)	%	11	2006 IPCC Guidelines [1]
C_{fi} coefficients for calculating NE_m	dimensionless	4-10	Expert estimation
C_a coefficients for calculating NE_a	dimensionless	37-56	2006 IPCC Guidelines [1]
Milk energy value	MJ/kg	16	Value range according to data of M. Shtompel et al., 2005.
$C_{pregnancy}$ coefficients for calculating NEp	dimensionless	27	2006 IPCC Guidelines [1]
Methane conversion factor	rel. u	7-9	2006 IPCC Guidelines [1]

Uncertainty values for GE in fodders for cattle at agricultural enterprises calculated according to the source data are within the range of 6-20%, in households – 6-10%. For sheep, uncertainty of GE values is in the range of 15-22%, depending on the sex-age group.

Results of calculation of the national EF uncertainty for the cows by agricultural enterprises and households are reported in Table A3.2.8.2 (Annex 3.2.8).

Estimation of GHG emissions for the reporting period was carried out with the same method and the same degree of detail. Data collection and processing during the entire time series has been carried out 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 illustrates the dependence of the methane emission trend in category 3.A Enteric Fermentation on the cattle population, which is the major factor regulating emissions.

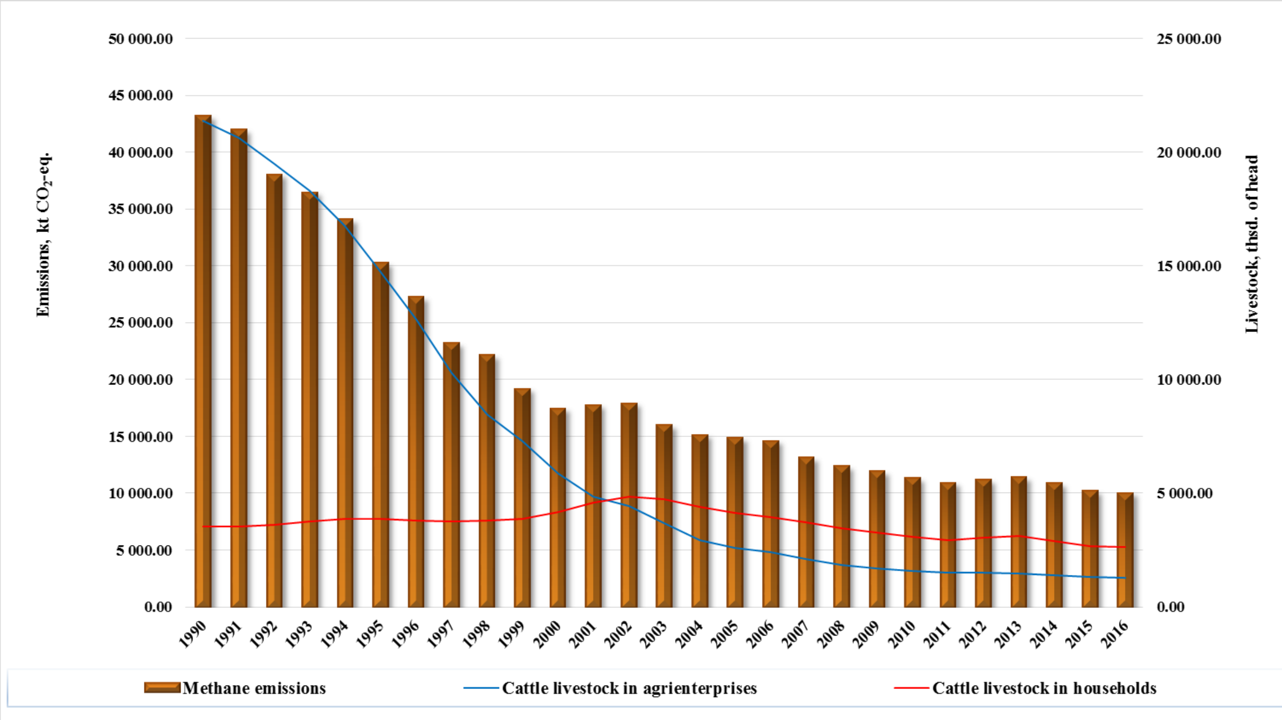


Fig. 5.4 Dependence of methane emission trends in category 3.A Enteric Fermentation on cattle population

The trend of methane emissions from enteric fermentation of animals consistently demonstrates the downward trend for cattle livestock in the public sector all through the time series.

5.2.4 Category-specific QA/QC procedures

Quality control and assurance are 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 and coefficients of countries with similar conditions, etc.

Check of the GE values calculated for each sex-age group of cattle and sheep was carried out by means of their conversion into food consumption units in the dry matter (kg/head per day) 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].

Methane emission factors from enteric fermentation of mature dairy cattle according to the CRF data were 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. In particular, the default factor was calculated based on averaged data for Eastern Europe, and its calculation method involves reverse deriving of GE values, i.e. based on productive energy consumption per animal growth unit, milk yield, etc., at the same time, the direct dependence between the amount of energy consumed with fodders and its conversion into products is not always observed [18]. The national approach simulates the flow of energy into the animal's body with fodders and takes into account specifics of feed rations depending on climatic zones of the country, handling conditions (agricultural enterprises or households), and the breed composition of cattle, and EF calculation with this method is built directly on the basis of the content of GE in feed rations, which makes it possible to more accurately estimate the methane-related energy loss.

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 5.6).

Table 5.6. 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	Republic of Austria	Czech Republic	Slovak Republic	Hungary
Mature dairy cattle	127.41	136.11	123.13	130.47	142.90	117.22	132.60
Mature non-dairy cattle**	67.51	43.33	50.74	59.90	55.44	57.40	55.58
Sheep	8.65	6.36	13.14	8.00	8.00	9.41	8.00

** Source: NIR of the Central and Eastern Europe countries, data for 2015, Ukraine – 2016 data.*
*** For reporting, Ukraine uses option B, therefore the emission factors are shown for growing cattle, given its dominant share in the structure of non-dairy cattle herds.*

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. 5.5).

Analysis of Fig. 5.5 points to the opposite direction of the trends considered for mature dairy cattle and growing – against the background of a sustained emission reduction trend, there is a steady increase in the EF. Trends in emissions and methane emissions factors for mature non-dairy cattle are the same, showing a downward trend due to the reduction of the proportion of cows in fattening and grazing in the mature non-dairy cattle livestock structure.

As is known, the livestock number is the key driver of the dynamics of emissions from cattle enteric fermentation. However, due to a significant increase in specific emissions from mature dairy and growing cattle, which can be traced in recent years (since 2003) against the backdrop of the reducing population of cattle in all categories of farms, their impact on the dynamics of total emissions has significantly increased.

The trend of national EF impacted by the following factors:

– the amount and structure of the consumed fodders;

– nutritional energy of the rations.

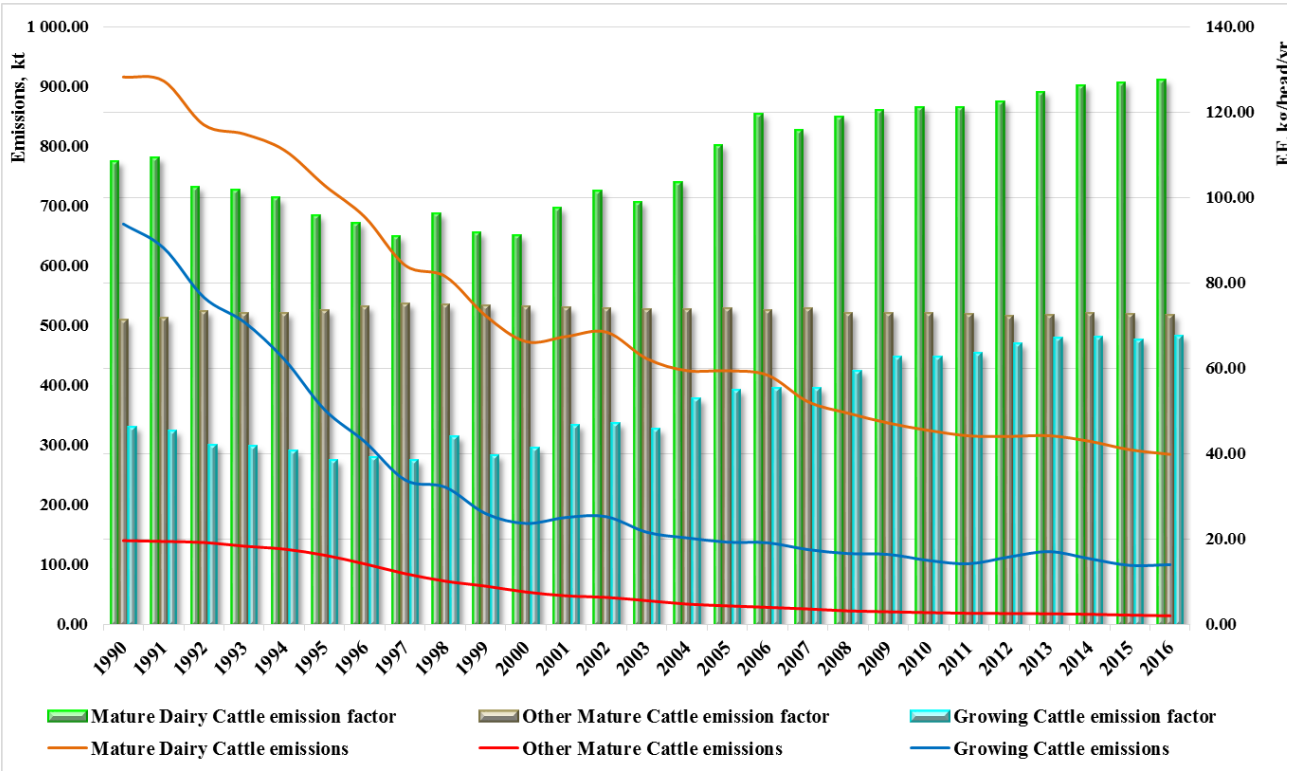


Fig. 5.5. Emission values and methane emission factors dynamics from cattle enteric fermentation

The modern detailed cattle feeding standards diets provide for ration balancing based on 25 to 30 indicators, including the dry matter and total nutrition value, protein content and quality, content of lipids, carbohydrates, cellulose, vitamins, macro- and micro-elements. The fodder need to maintain vital functions of the animal includes 1 f. u. per every 100 kg of live weight, for milk production –

0.5 f. u. per 1 liter, and for the average daily gain for calves under 1 year of 0.4-0.8 kg – 6 to 7 f. u. per 1 gained kg [10].

Fig. 5.6 shows the dependence of cattle enteric fermentation EF on fodder flow rate for all categories of farms for the reporting period.

Based on analysis of Fig. 5.6, we can conclude that the data on the amount of consumed fodders are closely linked with EF and determine their dynamics during the reporting period.

As a consequence of the collapse of the USSR, there were significant changes in the diet structure of cattle. Since 2000, there is a clear trend of growth of fodder consumption per head of cattle, and, accordingly, of EF, which is associated with an increased proportion of high-yielding cattle in the structure of cattle farms, to which higher feed rates are applied.

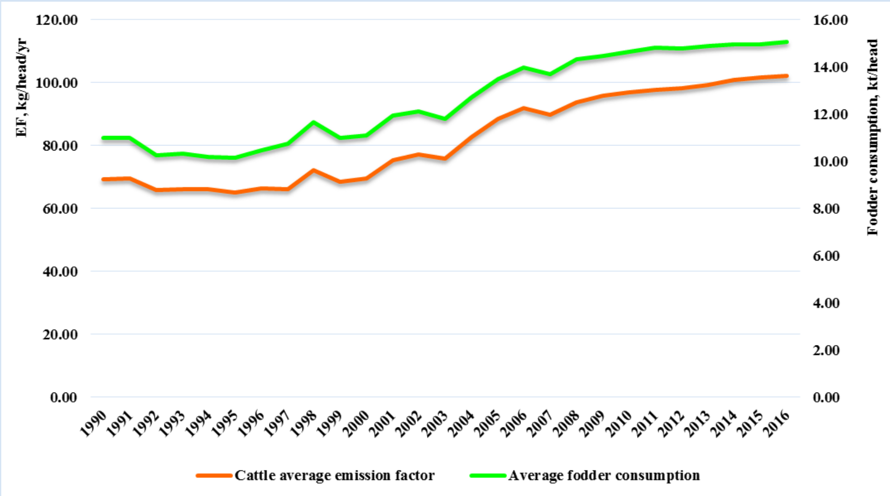


Fig. 5.6. Fluctuation of the cattle emission factor and amount of consumed fodder

Feed rations are directly dependent on physiological characteristics of cattle. Therefore, the optimal energy supply for animals may only be achieved with a balanced content of nutrients in fodders.

Concentration of GE in 1 kg of concentrated, succulent, coarse and other fodders for a specific sex-age group varies depending on the diet composition by climatic zones. For cows, the greatest amount of energy consumed per kg of concentrated and coarse fodders is typical for Polissia (17.2 and 15.4 MJ, respectively), of succulent and other ones – of the Steppe (4.3 and 3.9 MJ, respectively). In rations of other cattle, the largest amount of GE per kg of fodders is concentrated: in concentrates and coarse fodders – Polissia (17.2 and 15.2 MJ, respectively), in succulent and other ones – the Steppe (4.6 and 3.9 MJ, respectively).

Moreover, the factor determining EF dynamics is the ratio of concentrated, succulent, coarse and other fodders in the structure of cattle rations. As follows from analysis of the data in Table A3.2.2.3 (Annex 3.2.2), there is a clear trend of an increasing share of high energy content concentrates in rations of cows and other cattle since 2000 due to the partial substitution of succulent and other fodders. This trend is associated with establishment of large specialized dairy farms (with the capacity of more than 1,000 animals) and fattening farms, where the design is usually developed to handle livestock with high yield of dairy and meat products. To ensure a high level of milk production and weight gain, they increase the proportion of concentrates (application of the semi-concentrated and concentrated feeding types) in the diet balance of cattle at these types of farms. However, given the small weight proportion of concentrates in the cattle diet composition (dairy cows – 1-4 kg/day, for other cattle – 0.2-1.5 kg/day along the time series), the rate of the EF depends rather

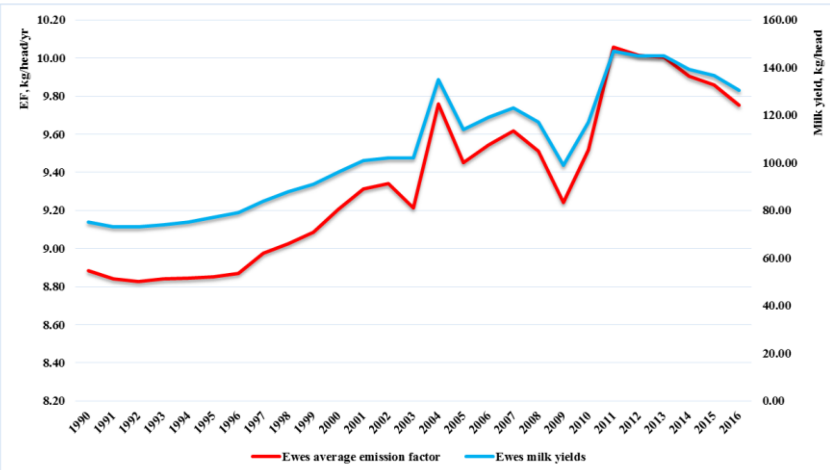


Fig. 5.7. The dependence of ewes EF on milk yield in 3.A Enteric Fermentation

on presence of coarse fodders in the rations, as they are consumed by animals in much larger volumes and have a reasonably high nutritional value. It is presence of significant amounts of coarse fodders (7-8 kg/head per day for dairy cows and 2-4 kg/head per day for other cattle in the reporting period) in the diet balance that explains the consistently high cattle EF in households compared with the public sector for most of the time series.

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% (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. 5.6). The discrepancy of the factors in this case may be explained 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 67.3% in 2015 with the proportional decrease in the share of growing sheep, to which the lowest EF apply.

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.

Quality assurance of the estimation results was ensured by means of an independent expert review with Tier 3 method for calculation of methane emissions from cattle enteric fermentation.

5.2.5 Category-specific recalculations

A time series recalculation of GHG emissions in 3.A Enteric Fermentation was held in this report (Table 5.7). The following reasons were for recalculation:

– reassessment of fodder consumption data;

– cattle sex-age groups harmonization according to Table 10.1 2006 IPCC Guidelines [1].

Table 5.7. Changes of methane emissions estimation in 3.A Enteric Fermentation, kt CH_4

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NIR 2017										
Mature dairy cattle	1 016.7	1 009.4	935.1	916.0	885.6	818.4	753.7	661.0	633.4	561.5
Other mature cattle	39.3	38.6	37.7	35.4	33.6	31.7	28.8	24.5	21.0	18.8
Growing cattle	670.0	629.8	547.2	505.9	443.2	359.1	305.4	241.5	229.4	185.3
Sheep	60.9	55.6	51.0	47.1	40.6	30.3	21.0	14.8	11.0	9.1
Other animals	50.1	48.6	46.3	45.1	44.0	42.9	40.8	37.4	36.1	36.2
NIR 2018										
Mature dairy cattle	915.9	909.2	835.8	820.6	793.3	734.4	681.4	600.7	582.1	516.3
Other mature cattle	140.2	138.8	137.0	130.8	125.9	115.7	101.1	84.8	72.2	63.9
Growing cattle	670.0	629.8	547.2	505.9	443.2	359.1	305.4	241.5	229.4	185.3
Sheep	60.9	56.0	51.4	47.5	41.0	30.6	21.1	14.9	11.1	9.2
Other animals	50.1	48.6	46.3	44.9	43.8	42.7	40.7	37.2	35.9	36.1

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NIR 2017										
Mature dairy cattle	511.2	515.1	520.4	471.8	447.3	444.5	435.0	388.9	367.7	350.3
Other mature cattle	16.2	14.4	13.8	12.4	11.1	10.7	10.4	9.5	8.2	7.6
Growing cattle	168.9	179.0	180.1	154.1	144.7	137.6	136.5	125.1	118.5	117.0
Sheep	8.2	7.9	7.8	7.4	7.5	7.4	7.7	8.5	9.3	9.7
Other animals	34.4	33.6	35.1	33.5	30.0	28.5	28.7	27.8	26.0	26.0
NIR 2018										
Mature dairy cattle	473.2	481.7	489.0	444.5	424.5	424.3	417.0	372.7	353.4	336.8
Other mature cattle	54.2	47.8	45.1	39.7	33.9	30.9	28.5	25.7	22.5	21.0
Growing cattle	168.9	179.0	180.1	154.1	144.7	137.6	136.5	125.1	118.5	117.0
Sheep	8.3	7.9	7.8	7.5	7.6	7.4	7.8	8.6	9.3	9.8
Other animals	34.2	33.5	35.0	33.5	30.0	28.5	28.7	27.8	26.0	26.0

Category	2010	2011	2012	2013	2014	2015	2016
NIR 2017							
Mature dairy cattle	337.2	327.4	326.0	327.0	317.9	299.9	
Other mature cattle	7.0	6.6	6.5	6.3	5.7	5.1	
Growing cattle	106.9	101.4	112.8	121.7	109.9	92.1	
Sheep	10.0	9.8	9.6	9.4	9.0	8.2	
Other animals	26.6	26.1	25.7	25.8	25.1	24.1	
NIR 2018							
Mature dairy cattle	324.6	315.4	314.4	315.6	306.4	292.2	284.5
Other mature cattle	19.6	18.5	18.1	17.8	16.8	15.4	14.3

Category	2010	2011	2012	2013	2014	2015	2016
Growing cattle	106.9	101.4	112.8	121.7	109.9	98.7	99.9
Sheep	10.0	9.9	9.6	9.5	9.0	8.5	8.1
Other animals	26.6	26.1	25.7	25.8	25.1	24.0	23.3

5.2.6 Category-specific planned improvements

To harmonize the methodology with the main principles of IPCC, assessment of the quality and completeness of the SSSU data an additional verification of the Tier 3 methodology for cattle enteric fermentation estimation [3] has been started.

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	2016	
3.B.1 Manure Management	CS, T1, T2	CS, D	CH_4	No	149.89	42.31	-71.77
3.B.2 Manure Management	CS, T1, T2	CS, D	N_2O	No	11.95	3.59	-69.99
3.B.2 Manure Management	T1	D	NMVOC	No	198.77	66.81	-66.39

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 is 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.

Methane emissions from Manure Management for the CRF animal categories are reported in Table 5.9. Along the 2010-2016 time period, a sharp reduction of CH_4 emissions from manure compared to the base 1990 was observed. First and foremost, this is 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 is determined by the change in the manure management practice over the time series.

Table 5.9. Methane emissions from Manure Management, kt CH_4

Category / sub-category	1990	1995	2000	2005	2010	2015	2016
3.B.1 Manure Management, total, incl.	149.89	91.90	46.42	41.99	48.25	44.91	42.31
Mature dairy cattle	59.37	34.31	16.45	14.51	11.54	10.55	10.31
Other mature cattle	10.08	6.16	1.90	1.05	0.74	0.60	0.56
Growing cattle	32.30	13.48	4.37	3.50	2.88	2.67	2.71
Sheep	1.79	0.88	0.23	0.20	0.27	0.23	0.22
Swine	30.70	26.60	15.08	12.93	21.17	18.45	16.51
Poultry	13.54	8.33	6.60	8.18	10.24	11.19	10.81

Category / sub-category	1990	1995	2000	2005	2010	2015	2016
Buffaloes	0.0043	0.0034	0.0024	0.0014	0.0004	0.0003	0.0003
Goats	0.06	0.11	0.11	0.11	0.08	0.08	0.08
Camels	0.0009	0.0009	0.0009	0.0012	0.0013	0.0013	0.0013
Horses	1.16	1.16	1.09	0.89	0.67	0.49	0.47
Mules and asses	0.01	0.00	0.00	0.01	0.01	0.01	0.01
Fur-bearing animals	0.38	0.34	0.13	0.19	0.21	0.20	0.19
Rabbits	0.49	0.53	0.45	0.43	0.44	0.43	0.43

Nitrous oxide emissions from MMS are reported in Table 5.10. The main source of emissions in this category is the manure that is stored in the solid form. The significant reduction in N2O 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.

Table 5.10. Nitrous oxide emissions from manure management systems, kt N_2O

Name of the MMS category	1990	1995	2000	2005	2010	2015	2016
3.B.2 Manure Management, total, incl.	11.95	7.75	4.30	3.94	3.78	3.70	3.59
*Direct emissions (total)**	6.94	4.60	2.57	2.32	2.14	2.06	2.00
Uncovered anaerobic lagoon	NO	NA	NA	NA	NA	NA	NA
Liquid system with natural crust cover	1.68	0.45	0.04	0.04	0.10	0.16	0.16
Solid storage	5.03	4.07	2.49	2.22	1.96	1.81	1.75
Composting	0.04	0.02	0.01	0.01	0.00	0.02	0.02
Poultry manure without litter	0.09	0.05	0.03	0.05	0.07	0.08	0.07
Pit storage below animal confinements	0.00007	0.00001	0.00001	0.00005	0.00005	0.00005	0.00005
Aerobic treatment	0.10	NO	NO	NO	NO	NO	NO
*Indirect emissions (total)**	5.01	3.16	1.73	1.61	1.65	1.64	1.58
Volatilization	5.01	3.16	1.73	1.61	1.65	1.64	1.58

** – emissions from manure in Pasture/Range/Paddock are reported in 3.D Agricultural Soils*

NMVOC emissions from Manure Management are reported in Table 5.11. Fluctuation key for NMVOC emissions is animal's livestock.

Table 5.11. NMVOC emissions from Manure Management, kt

Name of category	1990	1995	2000	2005	2010	2015	2016
3.B.2 Manure Management, total, incl.	198.77	150.00	95.75	78.92	71.59	68.99	66.81
Mature dairy cattle	68.02	61.76	41.80	30.42	21.60	18.53	17.97
Other mature cattle	13.88	11.14	5.07	2.81	1.80	1.44	1.34
Growing cattle	52.18	33.65	14.77	9.04	6.15	5.34	5.33
Swine	12.13	8.61	5.61	4.29	4.88	4.67	4.45
Sheep	1.39	0.68	0.17	0.15	0.19	0.16	0.16
Buffaloes	0.0036	0.0029	0.0020	0.0012	0.0003	0.0002	0.0002
Goats	0.27	0.45	0.47	0.45	0.34	0.34	0.35
Camels	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Horses	3.19	3.19	2.99	2.45	1.83	1.35	1.30
Mules and asses	0.03	0.00	0.00	0.02	0.02	0.02	0.02
Fur-bearing animals	1.09	0.96	0.37	0.53	0.59	0.58	0.53
Rabbits	0.36	0.39	0.33	0.31	0.32	0.32	0.32
Poultry	46.23	29.17	24.16	28.44	33.86	36.24	35.06

5.3.2 Methodological issues

The main source of emissions in 2016 was cattle Manure Management, the contribution of which reaches 41.88% of the total emissions of this category. The next most important emission subcategory is swine Manure Management – 28.60%. The proportion of emissions associated with poultry Manure Management during a year reaches 13.48%. The contribution of other categories of sources does not exceed 16.03%.

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" [27] was conducted to evaluate national opportunities for estimation of CH_4 emissions from manure management. The IPCC methodologies and some national methodological approaches, and country specific and default EF's are recommended by this paper.

Emissions of methane from manure were estimated according to Equation 10.22 of 2006 IPCC Guidelines [1].

The information base on the population of animals for CH_4 emissions estimation (Annex 3.2.1.2 and Tables A3.2.1.3.1-A3.2.1.3.2 of Annex A3.2.1.3) are statistical materials (Findings of cattle registry, Table No.7; Statistical bulletin: "The status of livestock in Ukraine" [20]; Statistical yearbook: "Animal Production of Ukraine" [19] and analytical study [2]. Cattle, swine, sheep, and poultry livestock at agrienterprises and households specialization by categories was 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 were calculated in accordance with Equation 10.23 [1] and reported in Annex 3.2.8 (Table A3.2.8.5). Default EF from Tables 10.14-10.16 [1] used for estimation methane emissions from manure management of other animals.

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). They are reported in Table A3.2.3.1 of Annex 3.2.3.

Default values of methane conversion factors (MCF) for each manure management system (MMS) used from the Table 10.17 [1].

SSSU do not collected MS data (fraction of livestock category manure handled using manure management system). That is why the time series MS values were estimated on the basis of expert estimation and reported in Table 5.12 and Annex 3.2.3 (Table A3.2.3.4).

Manure storage practices at agricultural enterprises is significantly different from manure storage practices in households. In this regard, the estimation for the said categories of farms was held separately.

Table 5.12. The manure management systems using in various types of livestock owners

Animal species	Agrienterprises	Households
Cattle	Liquid system with natural crust cover Solid storage Pasture/Range/Paddock* Composting	Solid storage Pasture/Range/Paddock*
Sheep	Solid storage Pasture/Range/Paddock*	Solid storage Pasture/Range/Paddock*
Swine	Uncovered anaerobic lagoon Liquid system with natural crust cover Solid storage Composting Aerobic treatment	Solid storage
Poultry	Poultry manure without litter Composting	Poultry manure without litter Pasture/Range/Paddock*

** – emissions from manure in Pasture/Range/Paddock are reported in 3.D Agricultural Soils*

Calculation of manure distribution by systems at agricultural enterprises was carried out based on the following provisions: SSSU data of the livestock of animals (Findings of cattle registry, Table No.7; Statistical bulletin: "The status of livestock in Ukraine" [20]); data of the statistical collection on the grouping of enterprises based on the available livestock of cattle and swine (Statistical yearbook: "Animal Production of Ukraine" [19]); Statistical form "NO.1-Waste"; departmental standards of technological design of livestock and poultry MMS operating on the farms and complexes [22-26]. The enterprise's capacity and specialization are the reason of MMS definition according to "Departmental standards of technological design" [22-26] as reported in Table 5.13.

Table 5.13. The manure management systems depending on the capacity and specialization of agricultural enterprises

Indicator	Manure management systems
Cattle (enterprises specialization)	
Dairy farms	Mechanical
Specialized dairy farms	Combined Mechanical and self-removal
Specialized fattening farms	Self-removal
Swine (head number)	
Up to 5000 head	Mechanical
10-12 thsd. head	Combined Mechanical and self-removal
24-54 thsd. head	Self-removal
More than 54 thsd. head	Hydro-removal

Solid and liquid systems, composting, and pasture, range and paddock are typical for cattle manure managing at agrienterprises. Manure stored in unconfined piles or stacks for a several months is 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 (MCF = 10%). According to expert opinion (№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 are 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 only solid systems used for cattle and swine manure managing at households.

At agricultural enterprises, poultry litter is usually removed mechanically by a belt conveyor or a delta transporter in case the poultry is 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 (goats, horses, sheep, rabbits, and fur-bearing animals), there is also the common practice of manure management in the solid storage, pit storage below animal confinements, and pasture, range, and paddock.

Manure and litter in households are kept exclusively in clamps with bedding (straw, sawdust, peat), or remains in paddocks. After several months of storage, the rotten manure is brought to the field [28]. Therefore, the share of livestock manure and litter of poultry by the MMS in households used according to expert estimation.

Duration of the grazing period depends on the regions where farm animals are kept, while the average for Ukraine is 165 days [6]. According to [22, 25], approximately 50% of the annual amount of cattle manure remain in grazing fields, and the same amount of poultry litter is lost if ranging in the territory. The same value for the amount of manure on pastures used in the calculations for goats, horses, and buffaloes (expert judgement). As a fact that the majority of sheep, camels, mules and asses are kept in Steppe, which have a high enough average annual temperature, the calculations reflect the fact that 74% of the annual amount of manure of sheep and 92% of camels, mules and asses remain on pastures (the IPCC default data on distribution of manure of these animals by systems are representative for the conditions of Ukraine).

The results of calculations of the shares of manure of animals by the systems of removal, storage, and use for the reporting period are reported in Annex 3.2.3 (Table A3.2.3.4).

The amount of volatile dry substances (Annex 3.2.3, Table A3.2.3.3) emitted in the manure of cattle and sheep was calculated according to Equation 10.24 [1], and for swine and poultry, this value was obtained with Equation 5.3.

GE values for cattle and sheep VS estimation used from 3.A Enteric Fermentation category (see chapters 5.2.2.1 and 5.2.2.2).

Cattle DE values for all sex-age groups at agrienterprises and households (Annex 3.2.3, Table A3.2.3.2) were calculated according to the digestibility of each fodder type that was identified in the expert judgment from The National Academy of Agrarian Sciences of Ukraine (№13700/10-16 on 13 Dec 2016).

Sheep DE (for good pastures, a well-preserved forages and diets with the addition of grain) was taken as 67.5% according to expert judgment from The National Academy of Agrarian Sciences of Ukraine (№20009/10-17 on 04 Aug 2017).

Default values of urinary energy (for cattle – 0.04, sheep – 0.02) used from 2006 IPCC Guidelines [1].

The source of cattle and sheep ASH values is an expert judgment and reported in 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 [29-30] were used.

$$VS = DM \times (1 - ASH), \qquad (5.3)$$

where:

VS – volatile solid excretion per day on a dry-organic matter basis, kg VS day^{-1};

DM – amount of manure excreted by animals, 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).

The values of the amount of manure excreted by swine and poultry in the dry matter, as well as the proportion of ASH in it are standard. The source of swine and poultry DM values (Annex 3.2.3, Table A3.2.3.1) is a judgment from the National Academy of Agricultural Sciences of Ukraine (№30432/10-17 on 28 Nov 2017), where they show an algorithm of its calculation according to "Departmental standards of technological design" [24-26].

It should be noted that for swine in households, in accordance with the standards [31], 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 are dominated by concentrated fodders, whereas in households – multi-component fodders.

5.3.2.2 Nitrous oxide and NMVOC emissions from Manure Management

5.3.2.2.1 Nitrous oxide emissions from Manure Management

For a full N_2O evaluation from manure management systems, the direct and indirect emissions were estimated.

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" [27] was conducted to evaluate national opportunities for estimation of N_2O emissions from manure management. The IPCC methodologies and some national methodological approaches, and country specific and default EF's are recommended by this paper.

Direct N_2O emissions from manure management systems

Direct N_2O emissions from MMS are 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 A3.2.8.6 (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 A3.2.1.3) are statistical materials (Findings of cattle registry, Table No.7; Statistical bulletin: "The status of livestock in Ukraine" [20]; Statistical yearbook: "Animal Production of Ukraine" [19] and analytical study [2]. Cattle, swine, sheep, and poultry livestock at agrienterprises and households specialization by categories was 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 A3.2.3.4) were applied in 3.B.1 Manure Management (methane emissions) category.

Based on the data available in Ukraine, the amount of Nex (Annex 3.2.3, Table A3.2.3.6) in manure composition of cattle sex-age groups was calculated in accordance with Equations 10.31-10.33. Cattle GE values for this estimation used from 3.A Enteric Fermentation category (see chapter 5.2.2.1). Crude protein fraction in diet of each cattle sex-age group calculated according to the judgment from the National Academy of Agricultural Sciences of Ukraine (№13700/10-16 on 13 Dec 2016). Database of milk production is SSSU source "Table No.15: Milk production", and for protein content in milk – expert judgment. Typical values of live weight for each sex-age cattle groups reported in Annex 3.2.2 (Tables A3.2.2.4 and A3.2.2.5). These values used for "Mature Dairy Cattle", "Other Mature Cattle" and "Growing Cattle" live weight calculation (Annex 3.2.2, Table A3.2.2.10).

Fodder consumption structure 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 were calculated in accordance with the Equation 5.4 and reported in Annex 3.2.3 (Annex 3.2.3, Table A3.2.3.5):

$$N_{ex} = DM \times fn \times 365, \tag{5.4}$$

where:

Nex – annual average N excretion per head, kg N animal^{-1} yr^{-1};

DM – the amount of manure excreted by species/group of animals, kg of DM 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 for the emission calculation in category 3.B.1 Manure Management (methane emissions) category. The source of sheep DM values (Annex 3.2.3, Table A3.2.3.1) is a National Academy of Agricultural Sciences of Ukraine 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 [23-26, 31].

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 (Annex 3.2.3, Table A3.2.3.6). 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 A3.2.3.6).

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 gender and age groups of animals in the agricultural enterprises and households (Table. 5.12), the corresponding average annual number of livestock and Nex (Annex 3.2.3, Table A3.2.3.5 and A3.2.3.7), and MMS typical share of processed manure (Annex 3.2.3, Table A3.2.3.4).

Indirect N_2O emissions from manure management systems

Indirect N_2O emissions includes the amount 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 are estimated from MMS volatilization only.

Manure management N_2O indirect emissions are 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 A3.2.1.3. 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 A3.2.3.4) were applied in 3.B.1 Manure Management (methane emissions) category.

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 [32]. In accordance with the methodological guidelines, estimation of NMVOC emissions from manure was carried out according to Equation 5.5 [32]:

$$E_{pollutant\_animal} = \mathrm{AAP}_{animal} \times EF_{poluutant\_animal} \quad , \qquad (5.5)$$

where:

$E_{pollutant\_animal}$ – pollutant emissions for each livestock category, tons yr^{-1};

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 A3.2.1.3) are statistical materials (Findings of cattle registry, Table No.7; Statistical bulletin: "The status of livestock in Ukraine" [20]; Statistical yearbook: "Animal Production of Ukraine" [19] and analytical study [2]. Cattle, swine, sheep, and poultry livestock at agrienterprises and households specialization by categories was performed in accordance with Tables A3.2.1.1.1 and A3.2.1.1.2 of Annex 3.2.1.1.

Tier 1 standardized emission factors for NMVOC were used by default [34] and are reported in Table 5.14.

Table 5.14. 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
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*

5.3.3 Uncertainty and time-series consistency

Uncertainty assessment was held under 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.

The uncertainty of statistical data on the population of cattle and poultry can be assessed 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 amount 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 5.15 shows uncertainties of the input data for estimating methane emission factors from manure and their sources.

Table 5.15. 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 anaerobic 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 pasture/range/paddock	rel. u	50	2006 IPCC Guidelines

Indicator	Measurement unit	Uncertainty	Source
Distribution of manure and litter by systems	rel. u	5	Expert judgment

The accuracy of default nitrous oxide emission factors was based on [1] and constituted 50.00%, and the estimated uncertainty of methane emission factors from manure of cattle and poultry was 13.06%.

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.

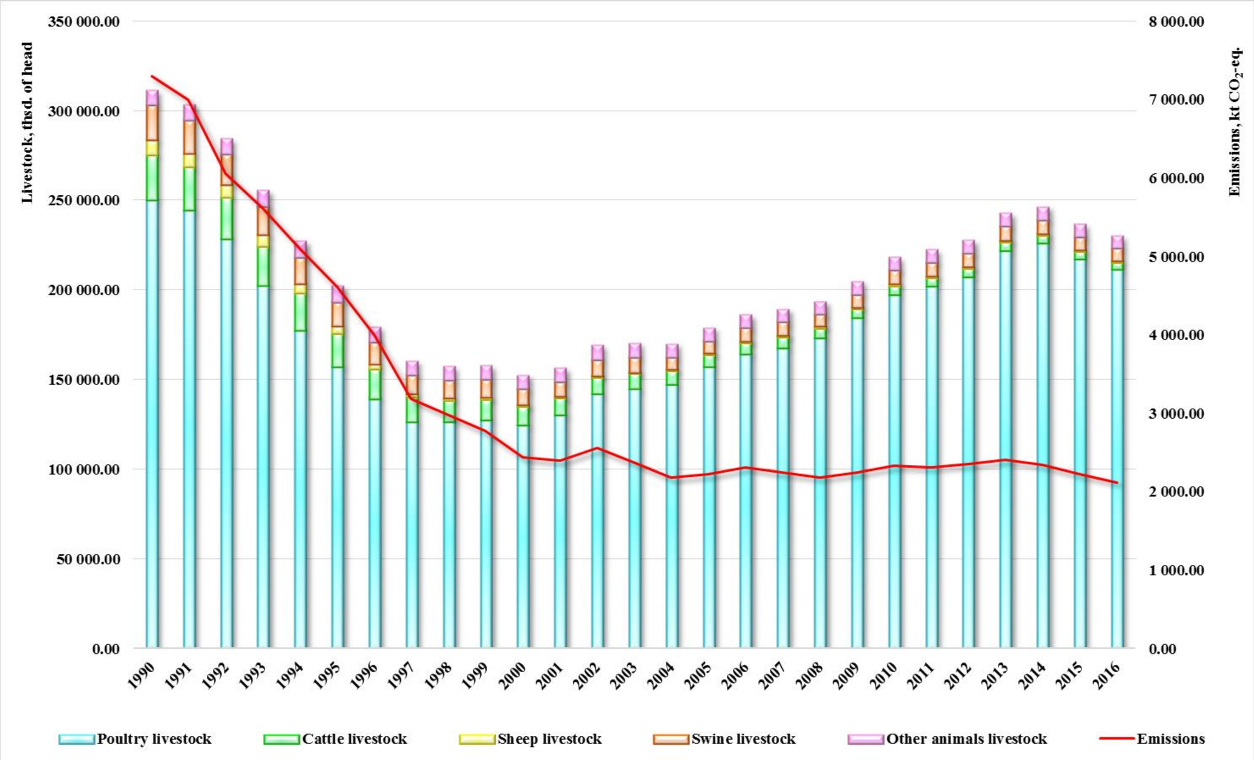


Fig. 5.8. Emission trends in category 3.B Manure Management, and those of cattle, swine, poultry and other animals populations

Against the background of the catastrophic decline in cattle population in the period of 1990-2016 (approximately 5 times), a growth of poultry and swine population has been 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 5.16). The main reasons of the EF's differences are the type of manure management systems and their range.

Table 5.16. 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	4.62	20.78	22.65	11.87	21.78	6.77	31.34
Other mature cattle **	1.83	6.92	5.01	4.99	9.04	1.85	8.80
Sheep	0.24	0.21	0.29	0.19	0.19	0.28	0.30
Swine	2.32	4.08	5.84	1.19	6.00	6.72	3.78
Other livestock	0.05	0.04	0.03	0.04	0.18	0.03	0.04
3.B Manure Management (direct nitrous oxide emissions)							
Mature dairy cattle	0.30	0.78	0.15	0.70	2.96	0.73	1.13
Other mature cattle **	0.15	0.40	0.09	0.36	0.87	0.25	0.47
Sheep	0.02	0.08	0.03	0.05	0.04	0.09	0.08
Swine	0.07	0.08	0.01	0.05	0.21	0.09	0.06
Other livestock	0.002	0.004	0.001	0.003	0.01	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	NE	NA	0.01

** Source: NIR of the countries, data for 2015, Ukraine – 2016 data.*
*** For reporting, Ukraine uses option B, therefore the emission factors are 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).

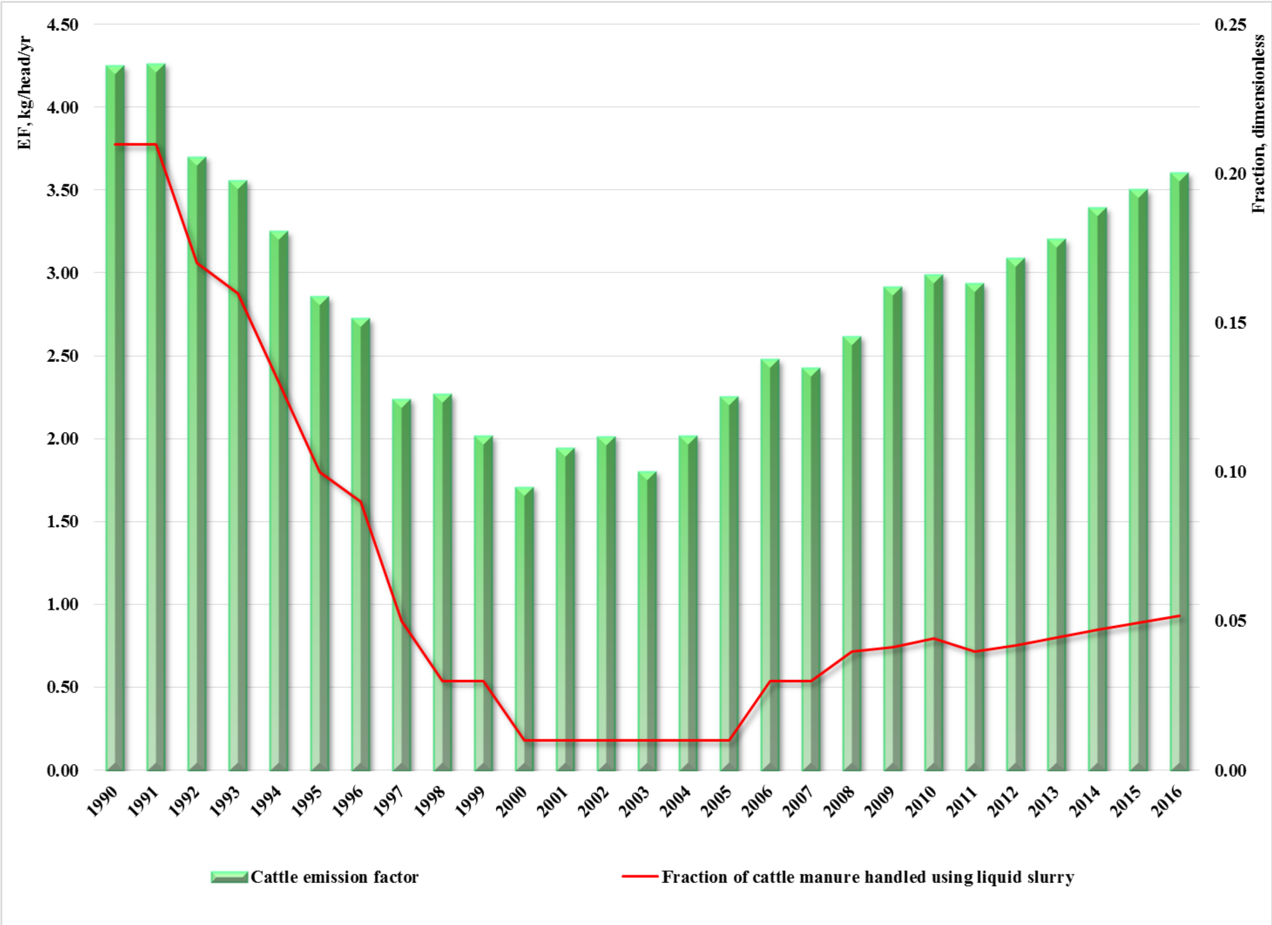


Fig. 5.9. Comparison of cattle emission factors and the shares of manure in MMS

Based on its results, it can be noted 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.

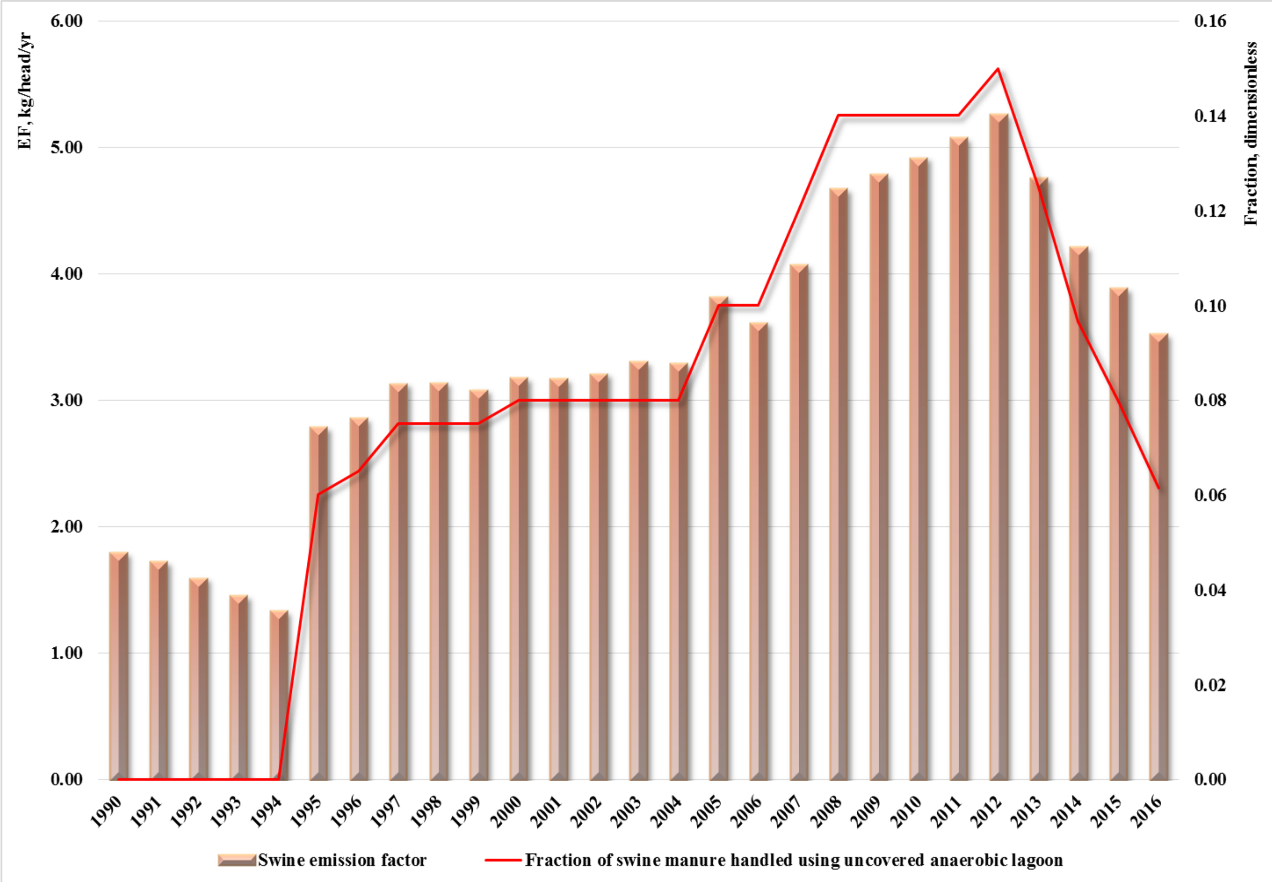


Fig. 5.10. Comparison of swine emission factors and the shares of manure in MMS

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 was performed.

5.3.5 Category-specific recalculations

A time series recalculation of GHG emissions in 3.B Manure Management was held and reported in Table 5.17. There are several reasons for recalculation, namely:

– recalculations, that are realized at the 3.A Enteric Fermentation category;
– cattle sex-age groups harmonization according to Table 10.1 2006 IPCC Guidelines [1];
– swine and poultry DM values clarification;
– cattle, sheep, swine, poultry and other animals Nex values clarification.

Table 5.17. Changes of GHG emissions estimation in category 3.B Manure Management, kt

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NIR 2017										
CH_4 emissions	200.2	192.1	166.0	149.1	129.5	124.8	109.0	89.6	83.2	79.3
N_2O emissions	22.9	22.0	19.6	18.3	16.8	14.6	12.8	10.6	10.0	9.1
NMVOC emissions	198.8	193.7	184.9	174.8	163.7	150.0	135.5	119.5	109.5	103.8
NIR 2018										
CH_4 emissions	149.9	143.9	122.1	110.6	96.1	91.9	80.0	63.9	58.0	53.8
N_2O emissions	12.0	11.4	10.1	9.6	9.1	7.8	6.7	5.3	5.1	4.8

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NMVOC emissions	198.8	193.7	184.9	174.7	163.7	150.0	135.4	119.5	109.4	103.8

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NIR 2017										
CH_4 emissions	70.6	69.2	74.8	71.3	66.7	70.5	74.6	75.4	75.8	79.1
N_2O emissions	8.2	8.3	8.7	8.1	7.6	7.7	7.9	7.4	7.2	7.2
NMVOC emissions	95.8	92.4	93.7	88.7	81.7	78.9	77.3	74.3	71.2	70.8
NIR 2018										
CH_4 emissions	46.4	44.8	47.8	44.4	40.3	42.0	44.4	44.4	44.0	45.4
N_2O emissions	4.3	4.3	4.6	4.2	3.9	3.9	4.0	3.8	3.6	3.7
NMVOC emissions	95.7	92.4	93.7	88.7	81.7	78.9	77.3	74.3	71.2	70.8

Category	2010	2011	2012	2013	2014	2015	2016
NIR 2017							
CH_4 emissions	84.6	85.4	87.1	89.7	88.6	84.8	
N_2O emissions	7.3	7.1	7.2	7.5	7.5	7.0	
NMVOC emissions	71.6	71.2	71.6	73.8	73.6	70.5	
NIR 2018							
CH_4 emissions	48.3	48.3	49.2	49.8	47.7	44.9	42.3
N_2O emissions	3.8	3.7	3.8	3.9	3.9	3.7	3.6
NMVOC emissions	71.6	71.2	71.6	73.8	72.7	69.0	66.8

5.3.6 Category-specific planned improvements

No improvements in this category are planned.

5.4 Rice Cultivation (CRF category 3.C)

5.4.1. Category description

Rice cultivation is one of minor methane sources in Ukraine. This fact explains the negligible GHG in category 3C Rice Cultivation (Table 5.18).

Table 5.18 Review of category 3C Rice Cultivation

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2016	
Rice Cultivation	T1	D	CH_4	No	8.66	3.56	-58.85

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).

In Ukraine, areas of rice fields are negligible. They were the lowest in 2014 and amounted to 10,200 hectares, and the largest – in 2011, 29,600 ha. In general, Ukraine has reducing rice cultivation areas.

Changes in the rice harvesting areas directly impacts the dynamics of methane emissions in the entire time series (Fig. 5.11) and determines the trend.

A sharp reduction in harvested rice acreage in 2014-2016 was due to absence of activity in the Autonomous Republic of Crimea.

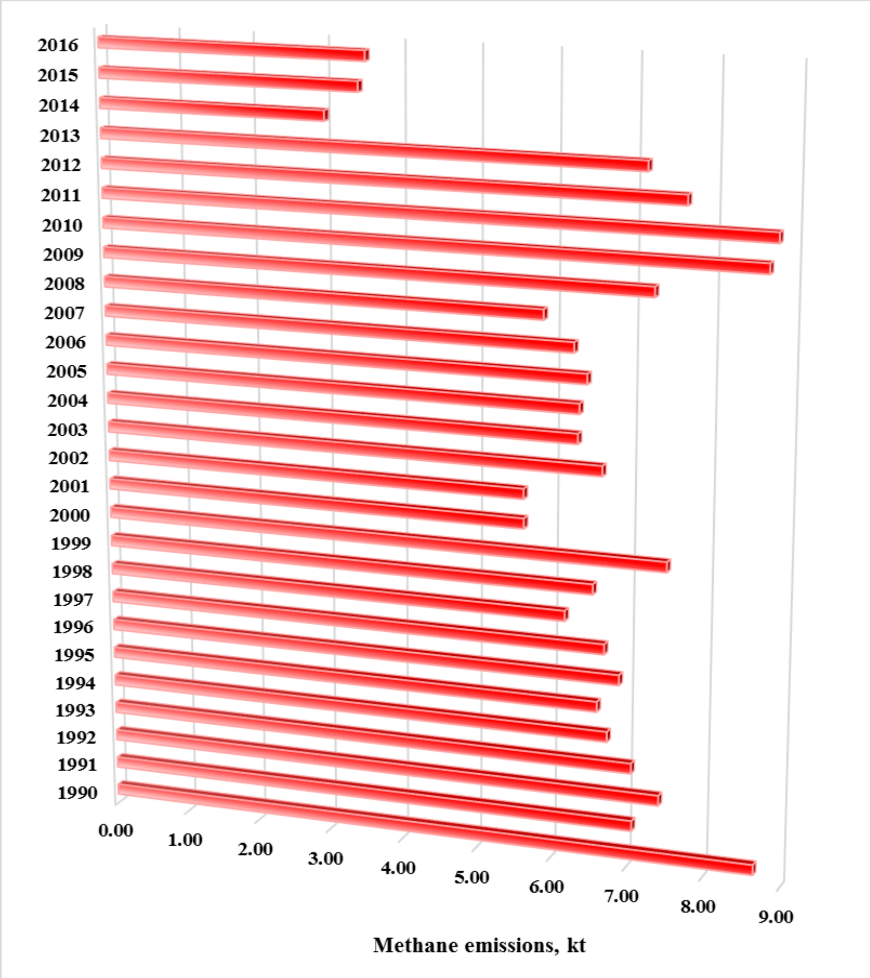


Fig. 5.11. Changes in methane emissions from rice cultivation

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 amount 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 are characterized as constantly flooded ones. The commonly used types are those where the vegetation period is 120 days. Rice is harvested once a year. Soil types used for rice cultivation – alkaline and brownstone alkaline.

Compost is 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).

For calculations, basic equation 5.1 was used, and an adjusted daily emission factor (Annex 3.2.8, Table 3.2.8.7) was determined based on equation 5.2 of the 2006 IPCC Guidelines [1].

As the starting point for calculation 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) was used, which by default 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].

The scaling factor to account for differences in water regimes during the cultivation period (SF_w) was used by default from Table 5.12 [1], the scaling factor to account for differences in the water regime before the season, before the cultivation period (SF_p) – from Table 5.13 [1], and the scaling factor both for the type and amount of organic fertilizers applied (SF_o) was calculated by using formula 5.3. from Table 5.14 [1].

Table 5.19 presents input data for estimation of methane emissions from Rice Cultivation.

Table 5.19 Activity data for estimation of methane emissions from rice cultivation

Indicator	1990	1995	2000	2005	2010	2015	2016
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
The scaling factor to account for differences in water regime during the cultivation period (SF_w)	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
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
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
The cultivation period of rice (t), days	120	120	120	120	120	120	120

5.4.3 Uncertainty and time-series consistency

Uncertainty estimation was performed based on 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 5.20).

Table 5.20. 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 were used from tables 5.11 to 5.14 of the 2006 IPCC Guidelines [1].

Over the entire reporting period, the same approach to collection of the basic information was applied, and calculation of GHG emissions was held based on 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

No recalculation of GHG emissions were performed in the category Rice Cultivation.

5.4.6 Category-specific planned improvements

No improvements are planned.

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 [33]. N_2O emissions in category 3.D Agricultural Soils are reported (Table 5.21).

Table 5.21. Review of category 3.D Agricultural Soils

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2016	
3.D.1.1 Inorganic N Fertilizers	T1	D	N_2O	Level/Trend	28.89	19.59	-32.20
3.D.1.2 Organic N Fertilizers	T1	D	N_2O		8.58	2.37	-72.43
3.D.1.3 Urine and Dung Deposited by Grazing Animals	T1	D	N_2O		12.79	4.27	-66.62
3.D.1.4 Crop Residues	CS	D	N_2O		46.26	32.65	-29.42
3.D.1.5 Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter	T2	D	N_2O		NO	18.60	100.0
3.D.1.6 Cultivation of Organic Soils	T1	D	N_2O		5.99	6.01	0.35
3.D.2.1 Atmospheric Deposition	T2	D	N_2O	Level/Trend	7.31	3.77	-48.37
3.D.2.2 Nitrogen Leaching and Run-off	T1	D	N_2O		10.01	9.64	-3.68

During the observation period, there was redistribution of the share of emissions among sources in category 3.D Agricultural Soils (Fig. 5.12).

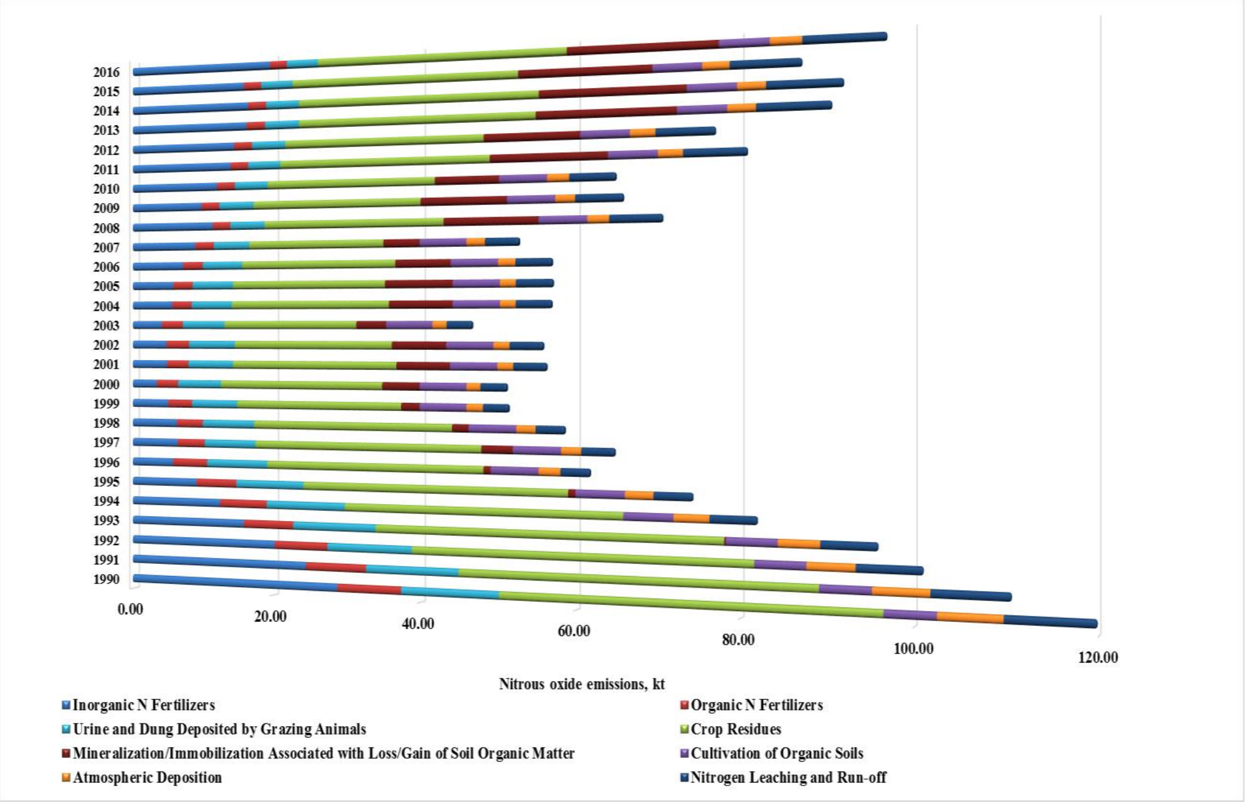


Fig. 5.12. Emission distribution in category 3.D Agricultural Soils

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 [33]:
– application inorganic N Fertilizers;
– application organic N Fertilizers;
– urine and dung deposited by grazing animals;
– crop residues, including nitrogen fixation;
– N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils;
– cultivation of organic 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" [33] was conducted to evaluate national opportunities for estimation of N_2O emissions from agricultural soils. The IPCC methodologies and some national methodological approaches, and country specific and default EF's are recommended by this paper.

Direct emissions of N_2O are 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] was 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, 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 are allocated separately and marked FR.

Synthetic fertilizer. Nitrogen emissions from application of nitrogen fertilization were calculated according to method that based on data from the statistical bulletin: "The application of synthetic and organic fertilizers for harvest of agricultural crops" [34] and analytical study [2]. FAO data (http://faostat.fao.org) and interpolation (Annex 3.2.5, Table A3.2.5.2) were 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 (sodium nitrate, calcium nitrate, ammonium nitrate, ammonium chloride and others) used in Ukraine, but SSSU provide only total annual amount values of these synthetic fertilizers (without their division into species). 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}) are not applied on managed soils.

The annual amount of nitrogen in introduced into soils manure was 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 is 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 $Frac_{CNST}$ were not used for N_{MMS_Avb} estimation.

Estimation of the amount of N in the managed manure, which is 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 keep record of the amount of N in sewage introduced into soils (F_{SEW}) and does not have data on the amount of other organic improvers used as fertilizers (F_{OOA}), thus these figures were not taken into account in 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, is taken into account only in F_{COMP}. Thus, the total annual amount of N in the compost F_{COMP} includes a compost that is produced from plant residues and compost obtained through the managed manure.

The amount of N in compost applied to soils was 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 was 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 were carried out based on Levin's method quoted in the research paper [36] on the basis 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 are shown in Levin's paper, an attempt was made to maximally take into account the factors indicated above. For that sake, regression equations were 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 are 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 the amount of 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 amount 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 5.6 [36]:

$$F_{CR} = \sum_i \{[(a_i \times P_i + b_i) \times f_{ai} \times (1 - Frac_{Remove}) + (c_i \times P_i + d_i)] \times f_{ai} + (x_i \times P_i + y_i) \times f_{ri}\} \times S_i \times 10^2 , \quad (5.6)$$

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 amount 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 are taken from the Statistical bulletin: "The area, gross harvesting and yields of crops, fruits, berries and grapes" [35] and analytical study [2]. The statistical bulletin contains data on all agricultural enterprises whose activities are 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 are renewed annually [37]. Similarly to herbs, it was 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 [28, 38-41]. 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 judgement.

For the crops where Levin's method offers no regression coefficients, the same data for biologically similar crops were used. The information base for determining taxonomic similarity of crops was the reference book for identification of crop plants [42-43]. In particular, for soybean, vicia, beans, lupine, broad beans and chick-peas, lathyrus, mung bean data on pea (the legume family) were 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 was based on vegetables. For vegetables, regression coefficients for coriander (Umbelliferae) were used. Castor (the Euphorbiaceae family) was 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 were used in the estimations.

Fires events are stratified by timing of burning: before or after crop harvesting. If fires occurred before the crops been harvested, that is accounted by SSSU in the Statistical bulletin [35], where areas and yield of harvested crops are reported. In the case of fires after crop harvest regional departments of The State Emergency Service of Ukraine 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 are reported in Table A3.2.5.3 (Annex 3.2.5).

In the inventory, it was assumed that the entire nitrogen accumulated by nitrogen-fixing rhizobia in roots of legumes was 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 were used from 2006 IPCC Guidelines [1].

Annual direct N_2O-N emissions from managed organic soils

The annual direct emissions of N_2O-N from cultivated organic soils are calculated based on histosols area data and default emission factor (Table 11.1 of 2006 IPCC Guidelines) according to Equation 11.1 [1].

Data on areas of peat soils covering all of their types were 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 3.2.5.4).

Annual direct N_2O-N emissions from urine and dung inputs to grazed soils

Emissions of N_2O-N from animal manure on pastures ($N_2O–N_{PRP}$) were 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 (5.3 and 5.4), as presented above and reported in Tables A3.2.3.5-A3.2.3.6 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 ($MS_{(T, PRP)}$) were the same as in 3.B.1 Manure Management (methane emissions) category (see Annex 3.2.3, Table A3.2.3.4).

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

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 are considered: synthetic N fertilisers (F_{SN}); organic N applied as fertilizer (F_{ON}); urine and dung N 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 mineralisation 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 are given 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}) were 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,, were used [44]. A spring application of synthetic N fertilizers is a widespread practice of its using, because inputting N, which was inputted in autumn, leached in nitrate form. Gaseous losses of N makes up 5-24% [44] when fertilizers applies under the crop. A country specific middle value (14.5%) of this diapason used for GHG emissions calculation (Annex 3.2.8, Table A3.2.8.8).

The share of nitrogen in organic nitrogen fertilizers introduced and nitrogen from urine and dung left by grazing animals, which is volatilized as NH_3 and NO_X and the EF for N_2O emissions estimation from N volatilization were taken as default values from 2006 IPCC Guidelines [1].

Leaching/Runoff

N_2O emissions from leaching and runoff of introduced or deposited nitrogen are estimated using Equation 11.10 [1].

The values of the annual amount of N from synthetic (F_{SN}) and organic (F_{ON}) fertilizers, N from urine and dung deposited by grazing animals on pasture, range and paddock (F_{PRP}), N returned to soils with crop residues, including from N-fixing crops and renewal/restoration of forage crops and pastures, as well as nitrogen mineralized in mineral soils due to loss of soil carbon from soil organic matter as a result of changes in land use or management (F_{SOM}) are calculated with the respective equations, as described in Chapter 5.5.2.1 Direct emissions of nitrous oxide from agricultural soils.

To estimate indirect N_2O emissions from leaching and runoff of introduced or deposited nitrogen, default values (Annex 3.2.8, Table A3.2.8.8) 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 was held under 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 be taken at the level of 6% [2].

Table 5.22 shows uncertainties of the values nitrogen loss shares and their sources.

Table 5.22. 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 E. Degodyuk et al., 1988, and expert judgement
The fraction of nitrogen lost as NH_3 and NO_X at manure storage in anaerobic lagoons	75	Value range according to data of E. Degodyuk et al., 1988, and expert judgement
The fraction of nitrogen lost as NH_3 and NO_X at liquid systems	38	Value range according to data of E. Degodyuk et al., 1988, and expert judgement
The fraction of nitrogen lost as NH_3 and NO_X in solid storage	33	Value range according to data of E. Degodyuk et al., 1988, and expert judgement
The fraction of nitrogen lost as NH_3 and NO_X at manure storage in other systems	33	Expert judgement
The fraction of nitrogen lost as NH_3 and NO_X at manure introduction into soil	50	2006 IPCC Guidelines
The fraction of nitrogen lost as NH_3 and NO_X from manure on pasture	50	2006 IPCC Guidelines
The fraction of nitrogen lost through leaching/runoff from introduced mineral nitrogen fertilizers in the Polissia	10	Expert judgement
The fraction of nitrogen lost through leaching/runoff from introduced mineral nitrogen fertilizers in the Wooded Steppe	35	Value range according to data of E. Degodyuk et al., 1988.
The fraction of nitrogen lost through leaching/runoff from introduced mineral nitrogen fertilizers in the Steppe	60	Value range according to data of E. Degodyuk et al., 1988.
The fraction of nitrogen lost through leaching/runoff from organic fertilizers introduced	43	Value range according to data of E. Degodyuk et al., 1988.

Uncertainties of activity data and default emission factors in category 3.D Agricultural Soils are presented in Table 5.23.

Table 5.23. 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	6	93.57
Indirect N_2O emissions	6	95.50

Estimation of direct emissions in category 3.D Agricultural Soils for the entire time series was carried out using the same method with the same degree of detail. The coordinated procedures for activity data collection and processing that were 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 were 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 2009-2016 these AD differ by 5-57%, 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 was 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

In category 3.D Agricultural Soils, recalculation of the entire time series was held. The reason for the recalculation were:

– recalculation in category 3.B Manure Management, data of which are used in estimation of direct and indirect emissions of nitrous oxide from managed soils;

– adjustment of the original data based on the SSSU's updated information.

Table 5.24 shows changes in GHG emissions in category 3.D Agricultural Soils.

Table 5.24. Changes in estimation of N_2O emissions in category 3.D Agricultural Soils, kt

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NIR 2017										
Direct N_2O emissions	121.2	113.6	104.9	100.7	86.9	79.7	68.3	70.4	64.3	56.6
Indirect N_2O emissions	32.8	30.4	27.5	25.7	22.0	19.6	16.3	16.6	15.1	13.1
NIR 2018										
Direct N_2O emissions	102.5	95.2	87.7	84.4	72.0	66.1	55.3	58.2	52.5	46.1
Indirect N_2O emissions	17.3	15.4	13.2	11.5	9.9	8.2	6.4	6.6	6.1	5.4

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NIR 2017										
Direct N_2O emissions	55.9	60.1	59.8	51.1	59.5	59.4	59.1	54.4	69.4	64.9
Indirect N_2O emissions	12.6	13.8	13.8	11.6	13.7	13.7	13.9	13.0	16.7	15.5
NIR 2018										
Direct N_2O emissions	46.1	50.1	49.6	41.6	50.4	50.4	50.1	46.1	61.5	57.4
Indirect N_2O emissions	5.1	6.2	6.3	5.1	6.5	6.7	6.8	6.7	9.2	8.4

Category	2010	2011	2012	2013	2014	2015	2016
NIR 2017							
Direct N_2O emissions	63.7	77.2	73.8	85.8	86.5	81.6	
Indirect N_2O emissions	15.5	18.9	18.2	21.2	21.4	20.1	
NIR 2018							
Direct N_2O emissions	56.4	70.1	66.7	78.5	79.6	75.5	83.5
Indirect N_2O emissions	8.5	10.7	10.3	12.2	12.4	11.7	13.4

5.5.6 Category-specific planned improvements

No improvements are planned.

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 are accounted for 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 5.25).

Table 5.25. Review of category 3.G Liming

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2016	
Liming	T1	D	CO_2	Trend	2592.08	140.09	-94.60

Emissions of carbon dioxide (CO_2) from the liming of agricultural soils (Fig. 5.13) decreased significantly over the time series.

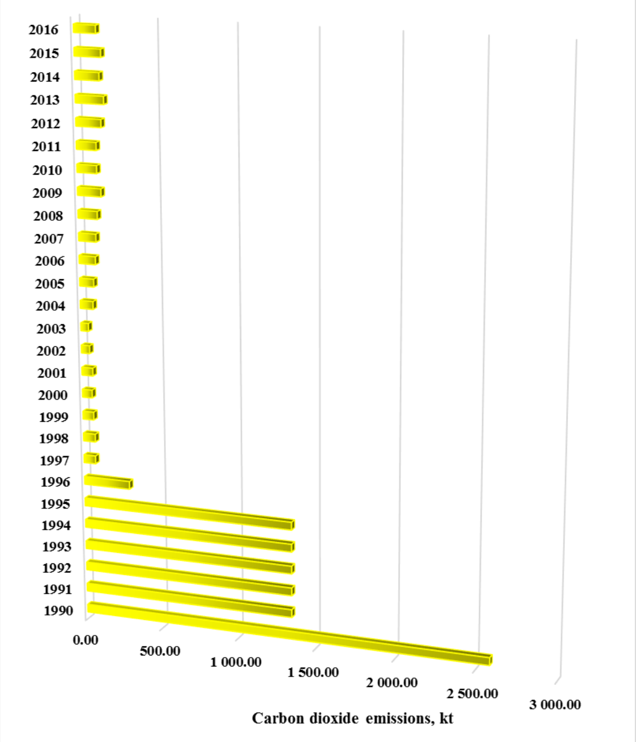


Fig. 5.13. Carbon dioxide emissions from liming of agricultural soils

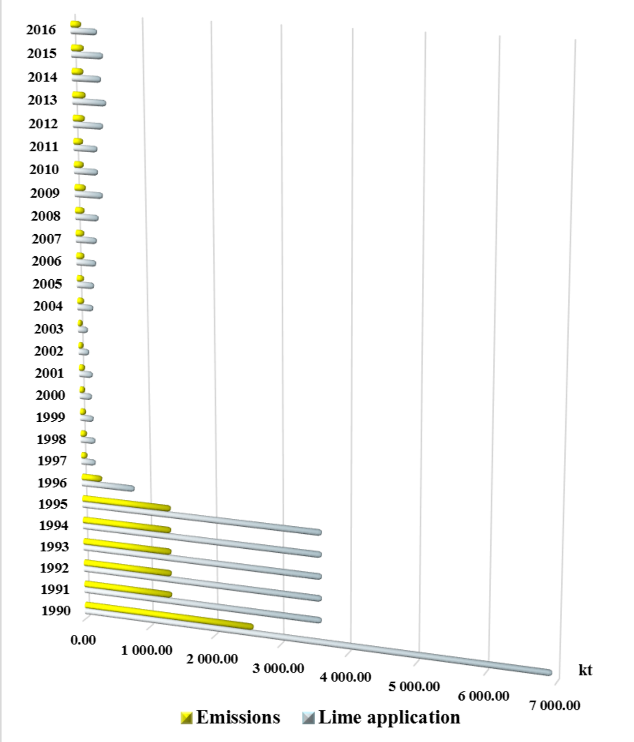


Fig. 5.14. The dependence of carbon dioxide emissions on the amount of liming material introduced

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 2016 carbon dioxide emissions decreased by -17.51%, which was caused by the grows of annual inputted lime materials (Annex 3.2.6, Table A3.2.6.1).

Liming used to reduce soil acidity and improve plant growth in managed systems, in particular on agricultural soils and in managed forests. For liming, ground lime used in Ukraine. There are no statistical information on the dolomite application.

Ground lime often contains a significant amount of inert material. Ground lime with different content of inert materials used for liming of soils. National statistics do not carry out research on the quality of applied ground lime. Industrial limestone fertilizers contain not less than 85% of the active substance [29-30].

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 ground lime;
– the active substance share;
– emission factor.

The source of data on liming materials introduced (in particular, ground lime) was Statistical bulletin: "The application of synthetic and organic fertilizers for harvest of agricultural crops" [34] and analytical study [2]. For those years where statistics are not available, the interpolation method used.

As the liming is performed in the first place by introduction of ground lime, 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 5.26 shows uncertainties of AD and the EF for category 3.G Liming.

Table 5.26. 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. Liming for the entire time series was 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 category 3.G Liming, a well correlated link between the AD and GHG emissions can be traced (Fig. 5.14).

5.8.5 Category-specific recalculations

In category 3.H Liming, recalculation of the entire time series was held (table 5.27). The reason for the recalculation was using a data of inert material share in the ground lime mater.

Table 5.27. Changes in estimation of CO_2 emissions in category 3.H Liming, kt

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NIR 2017	3049.5	1589.7	1589.7	1589.7	1589.7	1589.7	352.0	89.9	91.5	83.1
NIR 2018	2592.1	1351.3	1351.3	1351.3	1351.3	1351.3	299.2	76.4	77.8	70.6

Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NIR 2017	74.7	84.1	63.3	58.1	98.0	107.0	124.7	132.2	147.0	178.7
NIR 2018	63.5	71.5	53.8	49.4	83.3	90.9	106.0	112.3	125.0	151.9

Category	2010	2011	2012	2013	2014	2015	2016
NIR 2017	150.0	149.6	190.3	214.4	183.8	199.8	
NIR 2018	127.5	127.2	161.7	182.3	156.3	169.8	140.1

5.8.6 Category-specific planned improvements

No improvements are planned.

5.9 Urea Application (CRF category 3.H)

5.9.1. Category description

Urea (or carbamide) – $CO(NH_2)_2$ is used as nitrogen fertilizer in all soil and climatic zones of Ukraine. It is attributed to the group of amide fertilizers and the most concentrated solid nitrogen fertilizer. It is characterized by insignificant losses of nitrogen in soil. In soil, the amide form is 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 5.28).

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. 5.15).

Table 5.28. Review of category 3.H Urea Application

Category	Method applied	Emission factor	Gas	The key category	Emissions, kt		Trend, %
					1990	2016	
Urea Application	T1	D	CO_2	No	270.14	457.62	69.40

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.

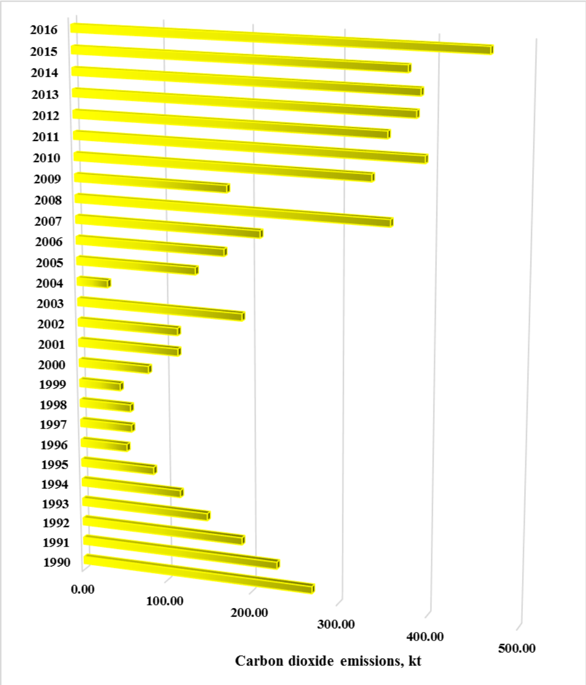


Fig. 5.15. Carbon dioxide emissions from urea application on agricultural soils

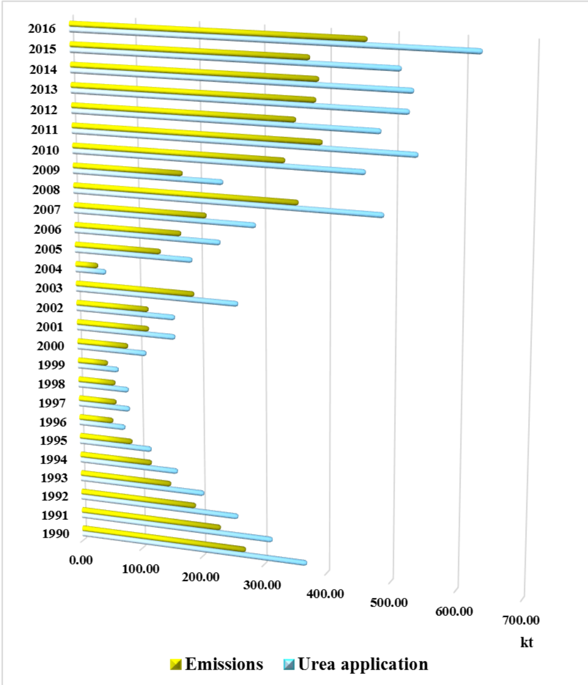


Fig. 5.16. The dependence of carbon dioxide emissions on the amount of urea introduced into soil

5.9.2 Methodological issues

Emissions estimation was 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 and emission factor.

The SSSU does not hold accounting of urea used as a fertilizer in agriculture. The source of data (Annex 3.2.7, Table A3.2.7.1) on the amount of urea used were FAO resources (http://faostat3.fao.org/download/R/RF/E). FAO data archive provides information for the periods of 2002-2004 and 2008-2012. To restore the data for 1990-2001, 2005-2007 and 2013-2016, extrapolation methods and analytical study [2] were applied.

The 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 was performed based on Tier 1 procedure of the 2006 IPCC Guidelines [1]. Table 5.29 shows uncertainties of AD and the EF for category 3.H Urea Application.

Table 5.29. 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 was 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 category 3.H Urea Application, a well correlated link between the AD and GHG emissions can be traced (Fig. 5.16).

5.9.5 Category-specific recalculations

No recalculation of GHG emissions was performed in category 3.H Urea Application.

5.9.6 Category-specific planned improvements

No improvements are planned.

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 2016 the resulting GHG removals were observed in the sector (Fig. 6.1).

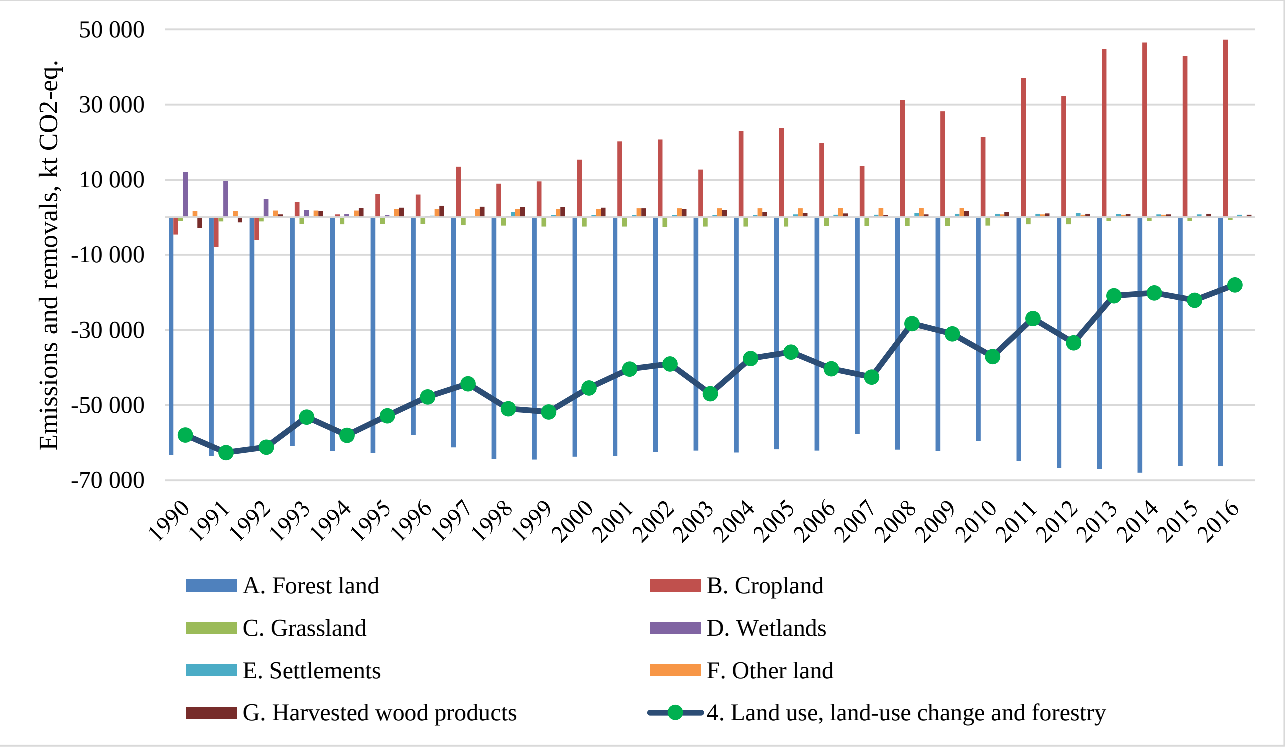


Fig. 6.1 Emissions and removals in the LULUCF sector in Ukraine in 1990-2016

The resulting values for the LULUCF sector vary from -62.6 Mt CO_2-eq. in 1991 to -18.0 Mt CO_2-eq. removals in 2016. In 1990 net removals was -58.0 Mt CO_2-eq.

Land-use areas representation in GHG inventory in the LULUCF sector was performed based on Approach 2. Ukraine is currently in a process to change activity data gathering procedure and its further processing aiming to address recommendations from ERT. It is expected to be finalized in 2019 submission. 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 fairly stable total GHG removal level is observed -57.7-68.0 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.

For the estimations both for UNFCCC reporting, and for the KP (3.3-3.4), the same information source from the anthropogenic activities in the forest sector updating database was used. The information in the database contains the characteristics of human activities under Article 3.3 KP by individual plots of forestry enterprises subordinated to the State Forest Resources Agency of Ukraine (Tier 2) and by the administrative categorization of activities under Article 3.4 (Tier 1). For detailed information regarding the database, see chapter 11.2.3.

GHG emissions and removals trend in Cropland category varies between -8.0 Mt CO_2-eq. removals in 1991 and 46.5 Mt CO_2-eq. emissions in 2016.

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 removals to 12.1 Mt C 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).

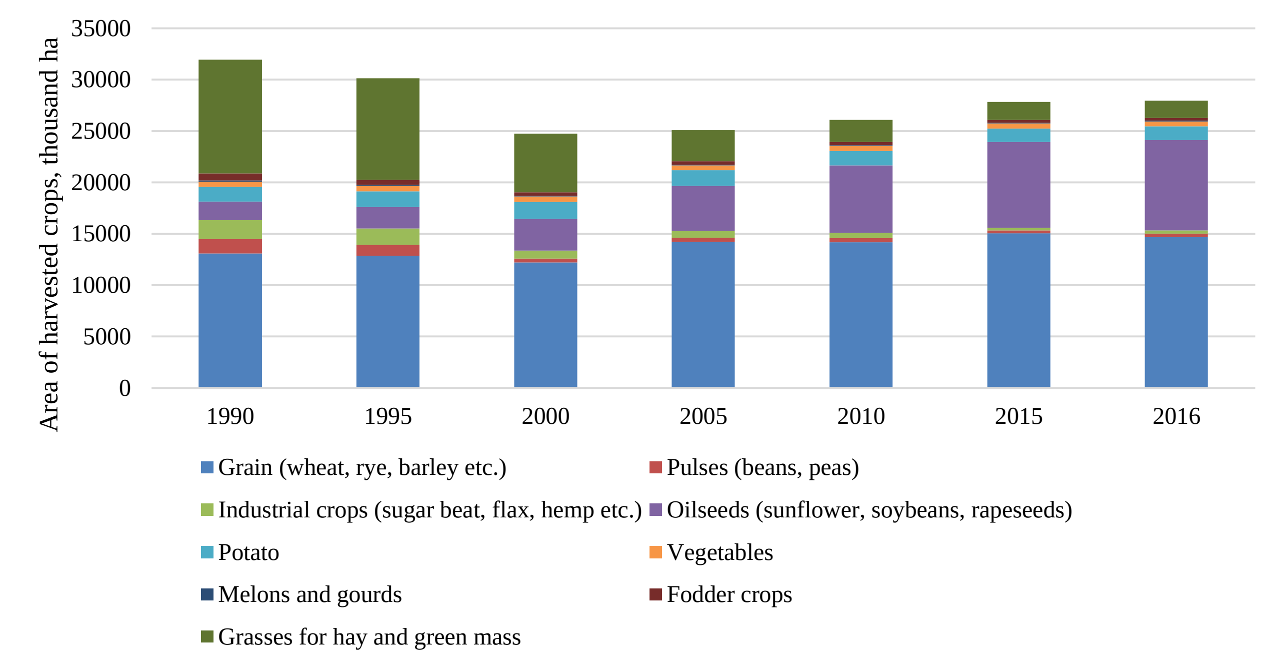


Fig. 6.2. Structure of crops grown on Croplands

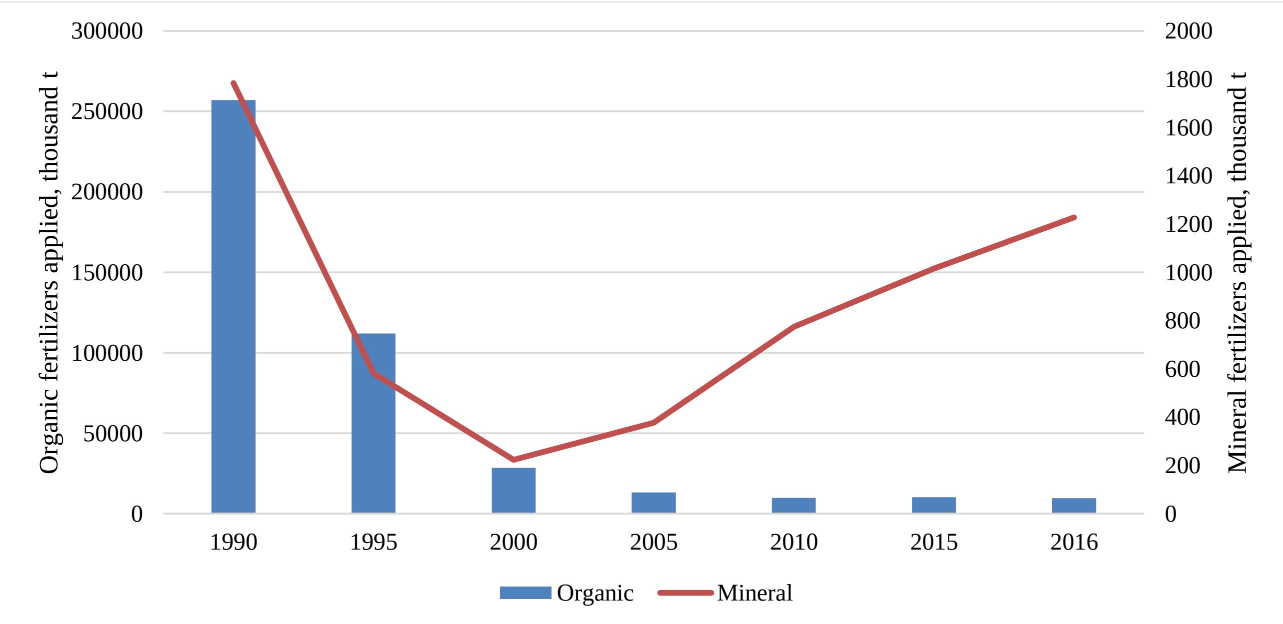


Fig. 6.3. Fertilizers input to Cropland

Grassland category is a net sink within entire time series 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 0.7 Mt CO_2-eq. in 2016. The most significant reasons for such trend is CSC in mineral soil pool, caused by land-use changes to Grassland category and change in areas and management of pastures and hay-fields.

Throughout the time series since 1990, emissions in the category Wetlands decreased in line with reduction in the area of peat extraction. Significant influence 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). Due to that the drop occurred from 12.0 Mt CO_2-eq. to 0.3 Mt CO_2-eq., what is approximately 98%.

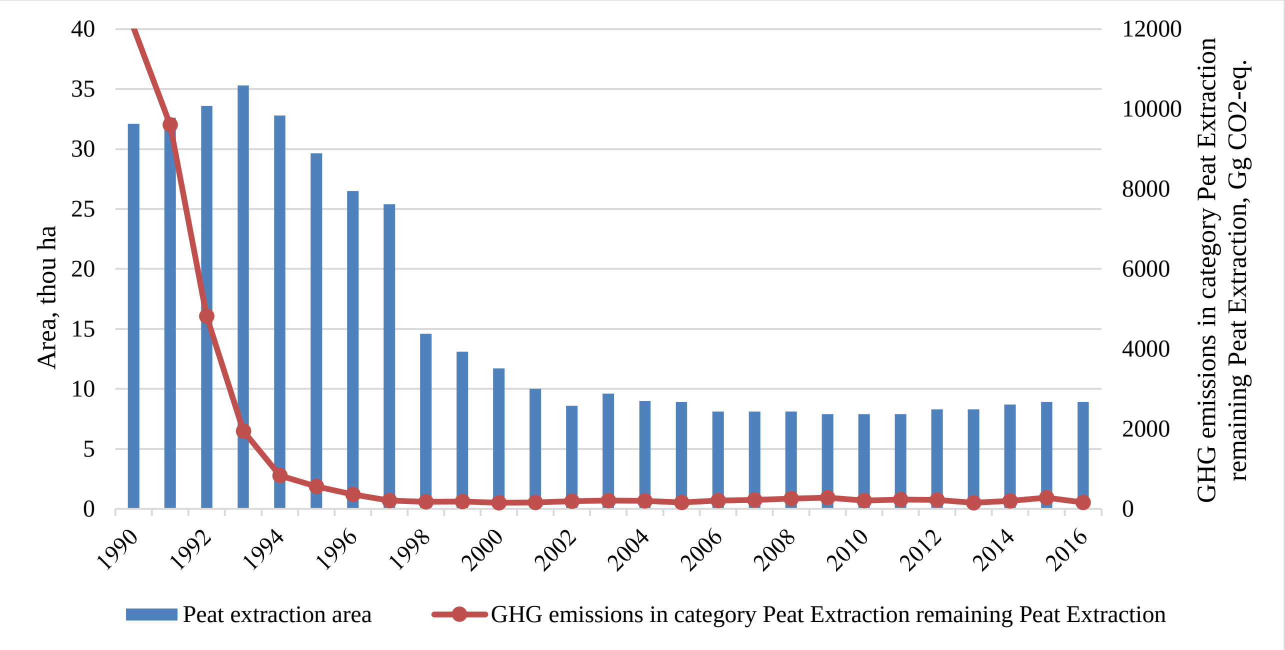


Fig. 6.4 Peat extraction areas and emissions in the category Wetlands in 1990-2016

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 3.6 Mt CO_2-eq. in 2008 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 2476300 m^3 in 2016. At the same time sawnwood production has declined to around 80% - from 7441 thousand m^3 in 1990 to 1739 thousand m^3 in 2016.

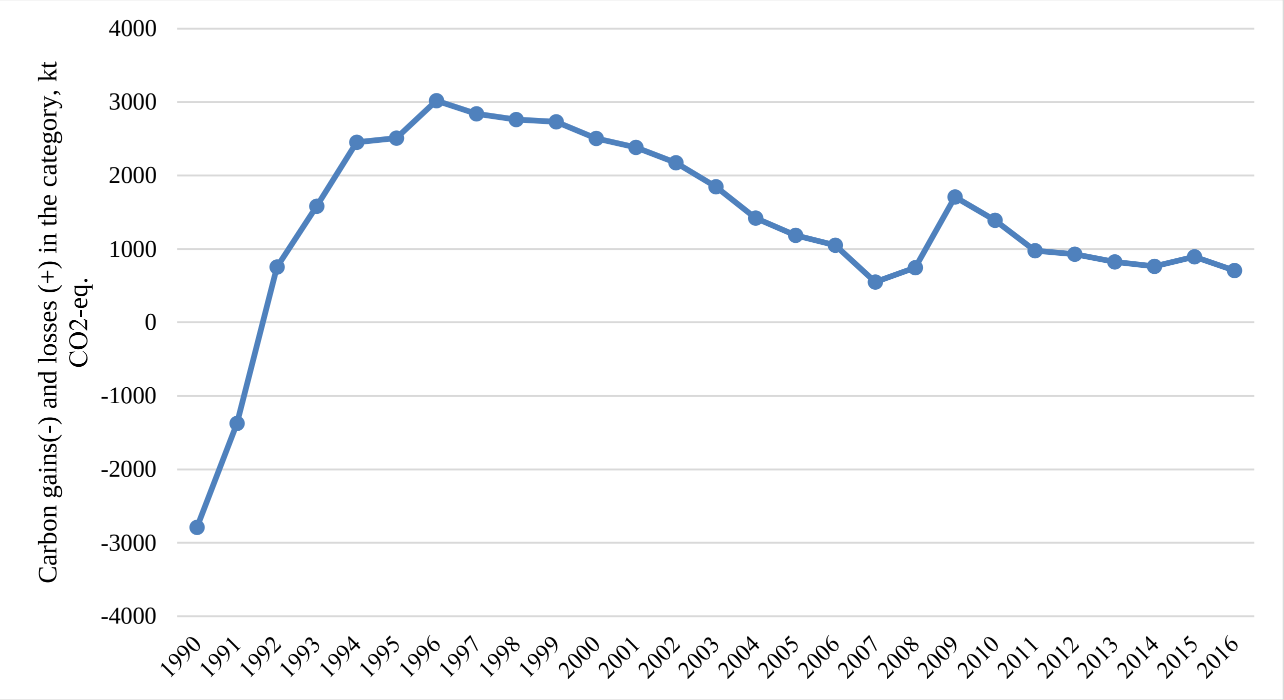


Fig. 6.5 HWP contribution into the total emissions/removals in the LULUCF sector

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.

In order to address recommendations of ERT with regard to land representation the Ministry of Environment and Natural Resources of Ukraine signed Memorandum of Understanding with the Space Research Institute. The Institute has experience in land-use identification using GIS technologies. This collaboration is expected to derive land-use matrixes for entire time series. According to the plan the results are expected to be used in 2019 submission.

Current NIR was prepared using approach and data sources as in 2017 submission.

The main source of information for this distribution of land in Ukraine is statistical reporting form No. 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 in CRF sector 5 reporting 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

Column # in form No. 6-zem	Category name	Category description, according to the guidelines for form No. 6-zem	Land-use category under 2006 IPCC Guidelines
5	Arable land	Land systematically cultivated and used for sowing perennial grasses, as well as for bare fallow and greenhouses. "Arable land"	4.B. Cropland

Column # in form No. 6-zem	Category name	Category description, according to the guidelines for form No. 6-zem	Land-use category under 2006 IPCC Guidelines
		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	
6	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
7	Gardens	Perennial plantations created to produce fruits, berries	4.B. Cropland
11	Hayfields	Agricultural land systematically used for hay mowing, including plots covered with tree and shrub vegetation by 20% or less	4.C. Grassland
12	Pastures	Agricultural land systematically used for grazing, including plots covered with tree and shrub vegetation by 20% or less	4.C. Grassland
21	Forests and other forest-covered areas, total, including	Land covered with forest (woody and shrub) vegetation and not covered with forest vegetation but provided for the forestry needs	4.A. Forest Land
23	Covered with woody and shrub vegetation	Forests and other forest-covered areas, including areas located on lands of other categories, is accounted in this land category. The specified category of land does not include data on agricultural land in forests and other forest-covered areas; agricultural buildings and courtyards, as well as utility paths on farmlands; swamp areas, under water. This category of land does not include green plantations within settlements; land under all other farm buildings and yards, except for land under industrial sites (for example, furniture factories, etc.)	4.A. Forest Land
28	Shrubs	Land covered with shrub vegetation (if the height is from 50 cm to 7 m, and the crown cover is larger than 20% of the territory)	4.A. Forest Land
34	Built-up land, total	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.E. Settlements
39	Land under operated peat extraction	Data on land under operated peat extraction: the land where peat extraction takes place, except for abandoned sites	4.D.1 Wetlands Remaining Wetlands
63	Open wetlands	Marshes, total	4.D. Wetlands
66	Dry open land covered with special vegetation cover	Data on dry open land with special vegetation cover, plots that are not cultivated and not covered with forest, but by more than 25% covered with tree and semi-tree vegetation with low nutritional properties; virgin steppe protected land	4.F. Other Land
67	Open land without vegetation or with little vegetation	Land not included into the above categories (rocks, sand, billows, and other land)	4.F. Other Land
72	Water	Inland water (rivers, canals, ditches, lakes, ponds, reservoirs)	4.D. Wetlands

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 activities under Article 3.3, 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. Activity data under Article 3.4, not accounting for the areas considered for activity 3.3. Based on use of: • information array of the Ukrainian State Forest Inventory Design Association (Forest Design); • 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	3.3, 3.4, 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 and fire areas and its types by the administrative and territorial division on forest land	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 (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

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
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
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

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 for the activities under Article 3.3 KP 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 between categories for the time series of 1990-2016, 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

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
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
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

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	7.94	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
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

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	10.63	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
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

Category prior to conversion	Category after conversion						Total
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
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

6.2 Forest Land (CRF category 4.A)

6.2.1 Category description

In line with the Forest Code of Ukraine [10], 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, impact 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 forest crops 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 [3].

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. Thus current submission retain division of Forest land remaining forest land as it was in previous NIR.

Managed forests include all forest land, on which there are anthropogenic activities of forest harvesting, forest planting, and forest maintenance conducted. Thus, managed forests are associated with the mandatory reporting activities in accordance with Article 3.4 of the Kyoto Protocol.

Unmanaged Forest land includes untouched (primary) forests[5], forests of Chornobyl exclusion zone, as well as uncovered by woody vegetation forest lands.

Annually there are 57.7-68.0 kt CO_2-eq. of GHG removed by the Forest Land category in total (Fig. 6.1). In 2016 Forest Land category is a sink of -66.3 Mt CO_2-eq., what is higher by 5 % as in 1990 (-63.3 Mt CO_2-eq.) and by 0.1 % as in 2015 (-66.2 Mt CO_2-eq.).

Difference in removal volumes during the reporting period is due to the felling volumes, emissions from fires, as well as 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

Calculations in the Forest Land category were carried out for all pools, except for mineral soil in sub-category 4.A.1 Forest Land remaining Forest Land. This assumption anticipates zero carbon stock change in forest soils and is based on findings of the research held in Ukraine [4]. Acknowledging need to apply Tier 2 method for soil pool 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 and dead organic matter were calculated under Tier 2 using national EFs. For organic and mineral soils, default factors were used for sub-category 4.A.2 Lands converted to Forest Land. Calculations in the category are presented in Annex 3.3.

The key sources of activity data 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, 2015 and 2016 with use of analytical study results [3].

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

[5] http://www.fao.org/documents/card/en/c/7d1e01d6-9d2e-4909-bb34-4657c6304a9a/

World Soil Database[6] almost all of the soils are high activity clay soils according to IPCC classification. 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 Annex 3.3.1.

During the GHG inventory for 1990-2016, estimation of nitrogen emissions from drainage of Forest Land was held 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.

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.

The total uncertainty of emissions/removals for the land-use category Forest Land is 17 %.

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

Data on biomass growth	25 %	Expert judgment
The ratio of above-ground and below-ground biomass	15 %	Expert judgment
Estimation of the amount of carbon in biomass	2 %	IPCC
Calculated uncertainty of land converted into forest land	50 %	Expert judgment

[6] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

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
Total uncertainty of carbon stored in biomass on Forest Land remaining Forest Land	9 %	Calculated
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	39 %	Expert judgment
Uncertainty of cutting data	10 %	Expert judgment
Uncertainty of data on fires	10 %	Expert judgment

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. Biomass gains resulted in 2 % difference with calculations with defaults, and biomass losses in 19 % difference. Total CSC in living biomass pool resulted in -1 % difference.

6.2.5 Category-specific recalculations

Estimation of CSC in Settlements converted to Forest Land was revised due to identified calculation error.

Also activity data from the State Forest Resources Agency of Ukraine about fires on lands of afforestation. Thus emissions for Forest Land remaining Forest Land and Land converted to Forest Land were reported separately for entire time series, with minor activity data clarifications. However total emissions from fires has changed slightly only when data was clarified.

The total values of GHG emissions in this category, as well as a comparison with the 2016 inventory are presented in Table 6.7.

Table 6.7. The change in GHG emissions in the Forest Land category for the time series from 1990 to 2015, kt CO_2-eq.

Year	NIR 2017	NIR 2018	Difference, %
1990	-63345.2	-63345.0	0.0
1991	-63530.5	-63522.0	0.0
1992	-61741.6	-61692.5	-0.1
1993	-60882.2	-60833.0	-0.1
1994	-62309.5	-62260.4	-0.1
1995	-62883.9	-62758.5	-0.2
1996	-58114.0	-57988.6	-0.2
1997	-61401.8	-61276.4	-0.2
1998	-64428.6	-64303.2	-0.2
1999	-64610.3	-64485.0	-0.2
2000	-63821.6	-63695.3	-0.2
2001	-63661.1	-63522.6	-0.2
2002	-62673.7	-62535.3	-0.2
2003	-62261.4	-62117.6	-0.2
2004	-62783.2	-62635.0	-0.2
2005	-61952.2	-61804.0	-0.2
2006	-62259.5	-62111.2	-0.2

Year	NIR 2017	NIR 2018	Difference, %
2007	-57843.7	-57695.5	-0.3
2008	-62047.1	-61898.9	-0.2
2009	-62371.2	-62223.0	-0.2
2010	-59670.7	-59522.5	-0.2
2011	-65108.7	-64968.8	-0.2
2012	-66777.2	-66678.2	-0.1
2013	-67195.6	-67096.6	-0.1
2014	-68136.4	-68037.3	-0.1
2015	-66224.1	-66201.0	0.0

6.2.6 Category-specific planned improvements

In order to address recommendations of ERT historical activity data collection about forestry has been started. This includes hard copy sources scanning and digitalizing, as well as gathering data from databases for more recent time to be able to use more accurate emission factors based on age of stands.

At the moment of submission hard copy papers were scanned for 1988, 1996 and 2002. These are the years of forest inventories performed in Ukraine. The information scanned includes institutional area allocation of forests, age structure of forests by area, and some reference indicators compared to previous forest inventory, with some differences of scope and structure of the information due to different forest inventory design at that time.

Since 2004 yearly electronic databases with all basic information with regard to forest inventories are available. It is expected that extracted information from these sources will allow to increase accuracy of estimation and address recommendation from ERT for LULUCF, and KP-LULUCF as well.

The areas of category is also expected to be revised due to work on revision of land-use change matrix.

The work is expected to be finalized and reported in 2019 submission.

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 2016 (47.3 Mt CO_2-eq.). Emissions has increased comparatively with 2015 by 10 %.

The key drivers for GHG emissions and removals are N-balance in mineral soil during crop grow (as it is calculated using nationally developed methodology), what is influenced mainly by crop structure 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 16-zem, 29-sg, 9-bsg. 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).

The data from 29-sg and 9-bsg forms of national statistics was corrected for 2014, 2015 and 2016 years using the results of analytical study for its use in the national inventory [3].

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. For the description of the estimation method, see Annex 3.3.2.

Calculation of carbon emissions from organic soil pool was held based on data of organic soil areas and the emission factors recommended for use in the 2006 IPCC Guidelines [1]. On response to recommendation from the ERT EF for temperate zone was applied.

In Ukraine, burning of crop residues on agricultural lands is officially forbidden [7], 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 emission factors 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 and DOM pools are estimated using national factors. Carbon losses from living biomass from conversions of Grassland are estimated using Tier 1 method and default emission factors.

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[7] almost all of the soils are high activity clay soils according to IPCC classification. 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 6.8.

Table 6.8. 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	

[7] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

CRF category	Gas reported	Method	Emission factor	Note
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;
- 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 38%.

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.

Table 6.9. Uncertainties in the Cropland category

Uncertainty of AD	6 %	Expert judgment
Distribution of harvested crop areas by climatic zones	13.5 %	Scientific research [9]
Nitrogen content in the primary crop products	3.0 %	Scientific research [9]
Nitrogen content in side-production	1.9 %	Scientific research [9]
Nitrogen content in crop residues (above- and below-ground)	18.1 %	Scientific research [9]
Nitrogen consumption by plants from crop residues	18.7 %	Scientific research [9]
Nitrogen inputs into plants from nitrogen mineral fertilizers	8.1 %	Scientific research [9]
Nitrogen inputs into plants from organic fertilizers	14.1 %	Scientific research [9]
Nitrogen inputs into soil from crop residues	9.9 %	Scientific research [9]
Nitrogen inputs into soil from organic fertilizers	14.0 %	Scientific research [9]
Nitrogen inputs into soil from symbiotic fixation	19.4 %	Scientific research [9]
Nitrogen inputs into soil from non-symbiotic fixation	23.0 %	Scientific research [9]
Nitrogen inputs into soil with precipitations	42.9 %	Scientific research [9]
Amount of humus mineralization of soils at crop growing	6.1 %	Scientific research [9]
Consideration of soil type of different mechanical composition areas	38.5 %	Scientific research [9]
Consideration of soil areas of various types of different mechanical composition by climatic zones	47.2 %	Scientific research [9]
Consideration of the C:N ratio for different types of soils	3.1 %	Scientific research [9]
Uncertainty level of carbon stock change factors in living biomass during its growth and loss	75.2 %	IPCC
Uncertainty of carbon emissions for organic soils	90.1 %	IPCC
Total uncertainty of carbon emissions for mineral soils	170 %	Calculated
Methane emission factor from burning of crop residues	22.7 %	Calculated
Nitrous oxide emission factor from burning of crop residues	27.5 %	Calculated

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 is presented below by groups of crops (calculations were performed by more detailed separation). The data in the table shows big difference in some of the crop groups (like industrial). However the totals estimated by national methodology are bigger by 29 and 42 percent than Tier 1 for above- and below-ground residues respectively.

Improvement of factors for Cropland category is in high need, so it is included into improvement plan (annex A8.2).

Table 6.10. 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	249881974	281839978	429958595	553339791	-42	-49
Beans and pulses	2862652	2608140	3109081	13146775	-8	-80
Industrial crops (incl. sugar beat)	29830240	39712374	1526400	11977620	1854	232
Oil crops	227751609	70427985	362504522	266402008	-37	-74
Vegetables (incl. potato)	50305020	27249985	76402507	34821338	-34	-22
Feeding crops	90825361	134395839	40987474	83067792	122	62
Total	653768211	557176999	914868453	963822824	-29	-42
Grasses (applicable to Grassland category)	5794449	16069938	13955168	10596476	-58	52

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

Recalculations in Cropland remaining Cropland were performed due to revision of N inputs from manure due to changes in Agriculture sector. Particularly there are revisions of manure in different manure management systems (for more details please see chapter 5.3).

Estimation of CSC in Settlements converted to Cropland was revised due to identified calculation error.

During QC procedures an error was identified of organic soil area in 1992, which was eliminated in current submission.

Table 6.11. The change in GHG emissions in the Cropland category for the time series from 1990 to 2015, kt CO_2-eq.

Year	NIR 2017	NIR 2018	Difference, %
1990	-401.4	-4642.3	1056.7
1991	-3522.1	-7954.7	125.8

Year	NIR 2017	NIR 2018	Difference, %
1992	-2647.1	-6032.4	127.9
1993	7638.4	4034.0	-47.2
1994	4605.6	794.9	-82.7
1995	10045.6	6216.2	-38.1
1996	9671.0	6051.9	-37.4
1997	16907.2	13477.0	-20.3
1998	12179.7	8915.3	-26.8
1999	12711.3	9528.7	-25.0
2000	18162.3	15352.3	-15.5
2001	22894.8	20196.6	-11.8
2002	23575.6	20659.2	-12.4
2003	15091.0	12647.7	-16.2
2004	25081.4	22922.7	-8.6
2005	25594.4	23804.1	-7.0
2006	21354.1	19773.6	-7.4
2007	14967.6	13606.6	-9.1
2008	32713.6	31302.5	-4.3
2009	28899.2	28220.5	-2.3
2010	22173.4	21406.1	-3.5
2011	37830.3	37061.4	-2.0
2012	33962.1	32252.8	-5.0
2013	46338.7	44689.9	-3.6
2014	48132.4	46484.0	-3.4
2015	44576.5	42893.8	-3.8

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.

Planned work of revision of land-use matrix is expected to deliver more accurate results regarding land areas converted to Cropland.

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 fattening 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. In 2016 there were 0.7 Mt CO_2-eq. of removals, what is lower than in 1990 by 22 % (0.9 Mt CO_2-eq. of removals) and by 22 % than in 2015 (0.9 Mt CO_2-eq. of removals).

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 forms of statistical reporting 16-zem, 29-sg, and 9-bsg. The data from this forms for 2014, 2015 and 2016 was corrected with the results of analytical study [3].

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 are 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 (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, 2015 and 2016 years [3].

The values of the areas that are legally seen within the land-use categories Hayfields and Pastures from statistical reporting form 6-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 the land-use category 4.C 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[8] almost all of the soils are high activity clay soils according to IPCC classification. 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.

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 6.12.

Table 6.12. 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

[8] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

CRF category	Gas reported	Method	Emission factor	Note
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 comsumption 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 24 %.

Data on input data and uncertainty factors are presented in Table 6.13. Uncertainties for default EFs were taken from 2006 IPCC Guidelines. Uncertainties for CS factors were derived from expert judgments.

Table 6.13. Uncertainties in the Grassland category

Uncertainty of activity data	6 %	Expert judgment
Distribution of harvested areas of agricultural crops by climatic zones	15 %	Scientific research [9]
Nitrogen content in the primary crop production	14.8 %	Scientific research [9]
Nitrogen content in crop residues (above- and below-ground)	3.7 %	Scientific research [9]
Nitrogen consumption by plants from crop residues	6.7 %	Scientific research [9]
Nitrogen inputs into plants from nitrogen mineral fertilizers	28.4 %	Scientific research [9]
Nitrogen inputs into plants from organic fertilizers	14.1 %	Scientific research [9]
Nitrogen inputs into soil from crop residues	13.0 %	Scientific research [9]
Nitrogen inputs into soil from organic fertilizers	17.0 %	Scientific research [9]
Nitrogen inputs into soil from symbiotic fixation	9.9 %	Scientific research [9]
Nitrogen inputs into soil from non-symbiotic fixation	36.0 %	Scientific research [9]
Nitrogen inputs into soil with precipitations	42.9 %	Scientific research [9]
Amount of humus mineralization of soils at crop growing	15.5 %	Scientific research [9]
Consideration of soil type areas of different mechanical composition	17.6 %	Scientific research [9]
Consideration of areas of various types of soils of different mechanical composition by climatic zones	47.2 %	Scientific research [9]
Consideration of the C:N ratio for different types of soils	3.1 %	Scientific research [9]
Uncertainty of carbon emissions for organic soils	90 %	IPCC
Combined uncertainty of carbon emissions from forest land converted to grassland	9 %	Expert judgment
Methane emission factor from burning on Grassland	39.1 %	Calculated
Nitrous oxide emission factor from burning on Grassland	47.6 %	Calculated

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 52 %, but more N from above-ground residues by 58 %.

Improvement of factors for national methodology is in high need, so it is included into improvement plan (annex A8.2).

6.4.5 Category-specific recalculations

Estimation of CSC in Settlements converted to Grassland was revised due to identified calculation error.

In this submission revise of N inputs with organic fertilizers have been revised in conjunction with recalculations in Cropland category (please see Chapter 6.3.5). That led to CSC in mineral soils revision in Grassland category for entire time series.

Table 6.14. The change in GHG emissions in the 4.C Grassland category for the time series from 1990 to 2015

Year	NIR 2017	NIR 2018	Difference, %
1990	897.3	-946.9	-205.5
1991	578.9	-1085.2	-287.5
1992	698.0	-1089.7	-256.1
1993	-148.0	-1828.1	1135.1
1994	-214.3	-1868.1	771.7
1995	-442.8	-1816.1	310.1
1996	-351.9	-1830.9	420.3
1997	-560.3	-2114.6	277.4
1998	-557.4	-2217.9	297.9
1999	-797.9	-2512.4	214.9
2000	-664.6	-2511.5	277.9
2001	-636.9	-2515.9	295.0
2002	-703.1	-2522.6	258.8
2003	-494.0	-2503.4	406.7
2004	-336.6	-2464.0	632.1
2005	-165.9	-2454.4	1379.6
2006	-44.1	-2420.3	5391.9
2007	45.9	-2434.3	-5400.7
2008	62.6	-2397.3	-3928.3
2009	437.7	-2353.1	-637.6
2010	550.5	-2196.0	-498.9
2011	932.9	-1914.3	-305.2
2012	949.1	-1898.0	-300.0
2013	1728.3	-1057.6	-161.2
2014	1809.0	-976.9	-154.0
2015	2037.8	-937.5	-146.0

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. Data on peat extraction volumes were obtained from the State Statistics Service of Ukraine (Table 6.15). Data on imports and exports of non-energy peat in Ukraine is not available. The conservative decision 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 8,8 kha in 2016. 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 6-zem. It was therefore decided that conversions occur either to Flooded Land or Other Wetlands.

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 6.15. 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

Amount of N_2O emissions from peat extraction was estimated using default EFs.

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 6.16.

Table 6.16. 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				

CRF category	Gas reported	Method	Emission factor	Note
management of organic and mineral soils - Peat extraction - 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	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 20%. 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 18%.

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 Wetland category in current submission.

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 converted to 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[9] almost all of the soils are high activity clay soils according to IPCC classification. 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 6.17.

Table 6.17. 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 2016 conversions of Cropland and Grassland and Other land occurred. Because of Tier 1 method of CSC calculations for these land-use conversions, total uncertainty level of GHG emissions in the category 4.E Settlements is 51 %.

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

CSC in SOM for Land converted to Settlements category were revised. Particularly calculation error was identified in calculation sheets. The results are presented below (please see table 6.18).

Connected with revision of CSC in SOM, direct and indirect N_2O emissions were also recalculated.

[9] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

Table 6.18. The change in GHG emissions in the 4.E Settlements category for the time series from 1990 to 2015

Year	NIR 2017	NIR 2018	Difference, %
1990	4.3	3.0	-29.3
1991	12.0	7.7	-35.5
1992	341.8	250.7	-26.7
1993	1080.5	216.1	-80.0
1994	1334.7	266.7	-80.0
1995	1335.0	266.8	-80.0
1996	1741.1	382.1	-78.1
1997	1738.3	346.8	-80.0
1998	3545.2	1378.3	-61.1
1999	2891.5	575.7	-80.1
2000	2890.9	575.2	-80.1
2001	2893.0	576.8	-80.1
2002	3094.8	627.2	-79.7
2003	3080.7	613.1	-80.1
2004	3094.7	623.3	-79.9
2005	3333.5	732.0	-78.0
2006	3313.4	673.1	-79.7
2007	3421.4	704.6	-79.4
2008	4175.2	1193.2	-71.4
2009	4008.3	895.4	-77.7
2010	4187.7	901.2	-78.5
2011	4317.5	925.8	-78.6
2012	4549.9	1079.1	-76.3
2013	3663.8	862.1	-76.5
2014	3410.4	733.8	-78.5
2015	3437.5	726.5	-78.9

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 converted to 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 [8] - 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 - 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 2016 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 in current submission.

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 converted to Other land.

6.8 Harvested Wood Products (HWP, CRF sector 4.G)

6.8.1 Category description

Fig. 6.5 shows the dynamics of carbon stock changes in the category of harvested wood products. In the time series from 1990 to 2016.

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	1 893 235	874 099
1991	6 106 000	1 735 830	804 842
1992	4 700 000	1 307 000	228 790
1993	3 882 000	1 036 000	145 290
1994	3 124 000	644 000	78 500
1995	2 917 000	596 000	85 200
1996	2 296 000	413 500	292 890
1997	2 306 000	398 800	264 000
1998	2 258 000	389 000	292 900
1999	2 141 000	434 000	310 900
2000	2 127 000	543 000	411 000
2001	1 995 000	726 000	479 900
2002	1 950 000	932 100	531 600
2003	2 197 000	1 045 000	618 037
2004	2 414 000	1 300 000	722 999
2005	2 409 000	1 509 000	768 010
2006	2 385 000	1 675 000	804 000
2007	2 525 000	2 029 000	937 001
2008	2 266 000	2 029 000	937 001
2009	1 753 000	1 578 000	813 999
2010	1 736 000	1 828 000	857 001
2011	1 888 000	2 081 700	986 998
2012	1 823 000	2 207 290	1 123 060
2013	1 804 000	2 277 690	1 079 350
2014	1 781 000	2 327 690	1 079 350
2015	1 534 500	2 377 690	1 079 350
2016	1 739 600	2 377 690	1 079 350

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.

GHG inventory in 4.G category was performed with stratification on Sawnwood, Wood-Based Panels and Paper and Paperboard with corresponding AD and EFs [12].

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 41 % 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 no recalculations in the category in the current submission.

6.8.6 Category-specific planned improvements

Currently Ukraine used FAO data for production of wood panels and paper and paperboard. In the previous submission it was planned to collect national data for these products for entire time series and report it in the current submission. But due to restructuring of the State Statistic Service reporting and confidentiality issues this work is planned to be done in the future submission.

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 2016 amounted to 12,145.93 kt of CO_2-eq.; including methane – 11,235.00 kt of CO_2-eq. (449.40 kt); nitrous oxide – 1,121.08 kt of CO_2-eq. (3.76 kt); and carbon dioxide – 8.98 kt, the increasing compared to the baseline 1990 (11,923.82 kt of CO_2-eq.) is 3.7 %. The largest contribution into total GHG emissions in the "Waste" sector in 2016 was made by methane emissions from solid waste landfills - 329.25 thousand tons (8,231.30 thousand tons of CO_2-eq.) or 66.57 % of the sector.

For details on the sector emission trends and emission values, see Fig. 7.1. and Table 7.1

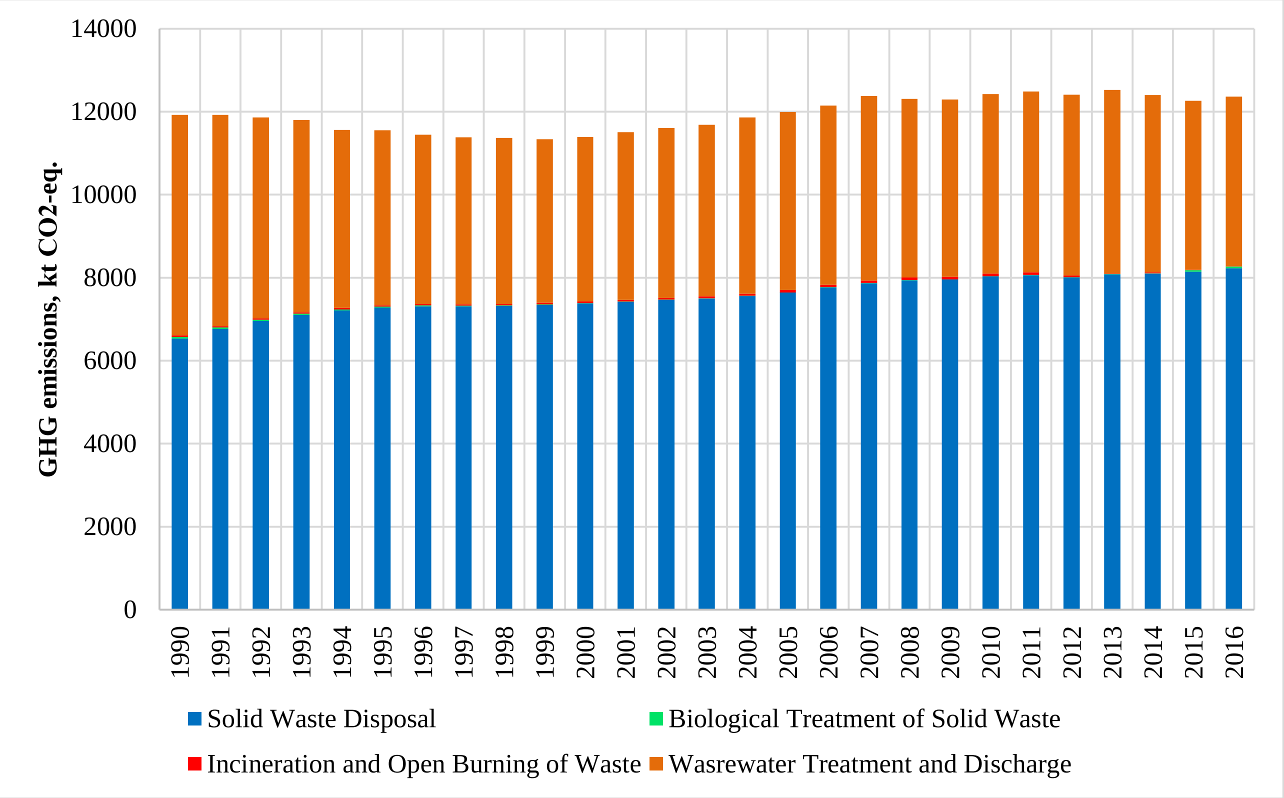


Fig. 7.1. GHG emissions in the "Waste" sector, 1990-2016.

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 9.3% - 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 of 2008. In 2013, GHG emissions in the "Waste" sector started to decrease constantly mainly due to the reduction of water consumption for industrial and household needs.

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	30.92	10181.93	1710.962	6534.85	34.36	36.17	5318.44	11923.82
1995	27.83	10212.50	1307.7283	7278.76	23.23	31.23	4214.85	11548.06
2000	35.84	10188.98	1164.5397	7376.58	9.71	39.65	3963.42	11389.36
2005	51.63	10707.21	1235.8305	7639.24	5.10	57.20	4293.14	11994.67
2010	53.47	11150.16	1216.4064	8035.20	3.03	58.93	4322.88	12420.04
2011	50.70	11219.17	1217.5329	8060.61	5.49	57.69	4363.62	12487.41
2012	35.96	11140.33	1229.6458	8003.23	6.41	39.27	4357.03	12405.93
2013	4.05	11277.73	1239.0489	8082.15	7.33	5.17	4426.17	12520.82
2014	14.35	11193.90	1190.0021	8094.76	12.37	16.75	4274.37	12398.24
2015	10.44	11119.59	1128.3663	8141.32	38.95	12.04	4066.08	12258.39
2016	8.98	11235.00	1121.0817	8231.30	34.68	11.32	4087.77	12365.07

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

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 2016 they have increased to 329.25 kt - by 25.96 %.

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 2011-2016, methane emission fluctuations mainly were caused by landfill gas recovery.

Methane emissions from solid waste disposal for 1990-2016 are shown at figure 7.2.

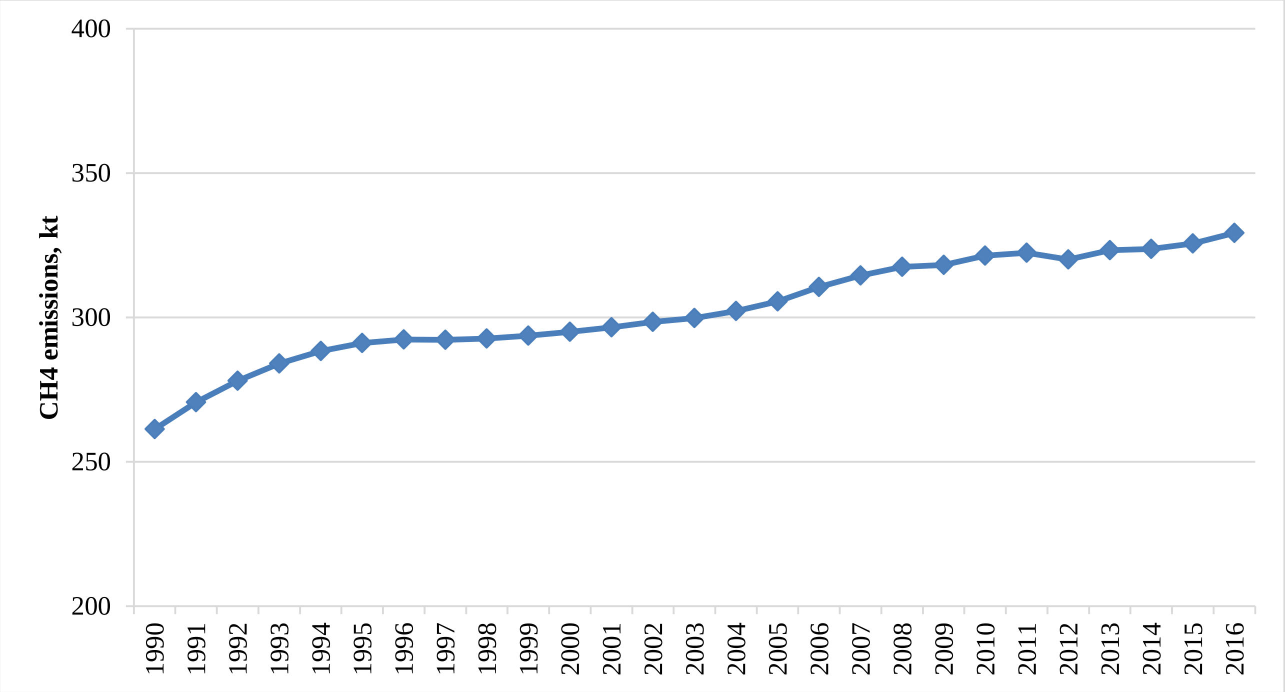


Fig. 7.2. Methane emissions from solid waste disposal, 1990-2016

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:

$$Q(t) = \sum_{j=1}^{m} \sum_{i=1}^{n} A \cdot k_j \cdot MWS_i \cdot MWS_{j,i} \cdot L_{0\ j,i} \cdot e^{-k_j \cdot (t-x)}, \quad (7.1)$$

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:

$$A = (1 - e^{-k_j})/k_j\ , \quad (7.2)$$

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:

$$DOC_j \cdot DOC_F \cdot F \cdot 16/12 \cdot MCF_i \ , \qquad (7.3)$$

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:

$$Q(t)^{em} = [Q(t) - R] \cdot (1 - OX, \qquad (7.4)$$

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[10]) 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 waste landfilled also includes the MSW landfilled illegally. Its share 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 Regional Development, Construction, Housing and Communal Services of Ukraine, 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 2010-2016 were taken from form No. 1 – waste "Waste Management" with regard to class 4 of hazard waste 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.

In 2016, 78 % of population was covered by centralized MSW collection system in Ukraine that corresponds to all urban and partly rural areas. MSW, generated at the areas covered by centralized MSW collecting system was firstly temporarily stored in containers.

22 % of population was not covered by centralized MSW collection in Ukraine that corresponds to the largest part of rural areas. According to the official responses provided by the regional

[10] http://ukrstat.gov.ua/

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).

Mix of MSW generated at the all territories (all 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.

Partly MSW generated at the territories not covered by centralized MSW collection system was self-organized transported by the rural population directly to the landfills.

As a result of the temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol and territories of the Donetsk and Luhansk regions by the Russian Federation waste generated (and further landfilled, incinerated, composted etc.) at the above mentioned territories wasn't included in official statistics for 2014-2016.

To cover the whole territory of Ukraine, the analytical study which includes different approaches, particularly extrapolation, expert judgement and other math and statistical methods [25] was used for 2014. In 2015 and 2016, waste generated at the temporary occupation the Autonomous Republic of Crimea and the city of Sevastopol was estimated based on population changes, for temporarily occupied of the Donetsk and Luhansk regions was considered the common trend of official statistics.

Taking into account the above stated the total amount of MSW landfilled was equal to 13.48 million tons, industrial waste – 40.39 thousand tons in 2016.

Waste management practices in Ukraine for 2016 schematically is shown at Figure 7.3

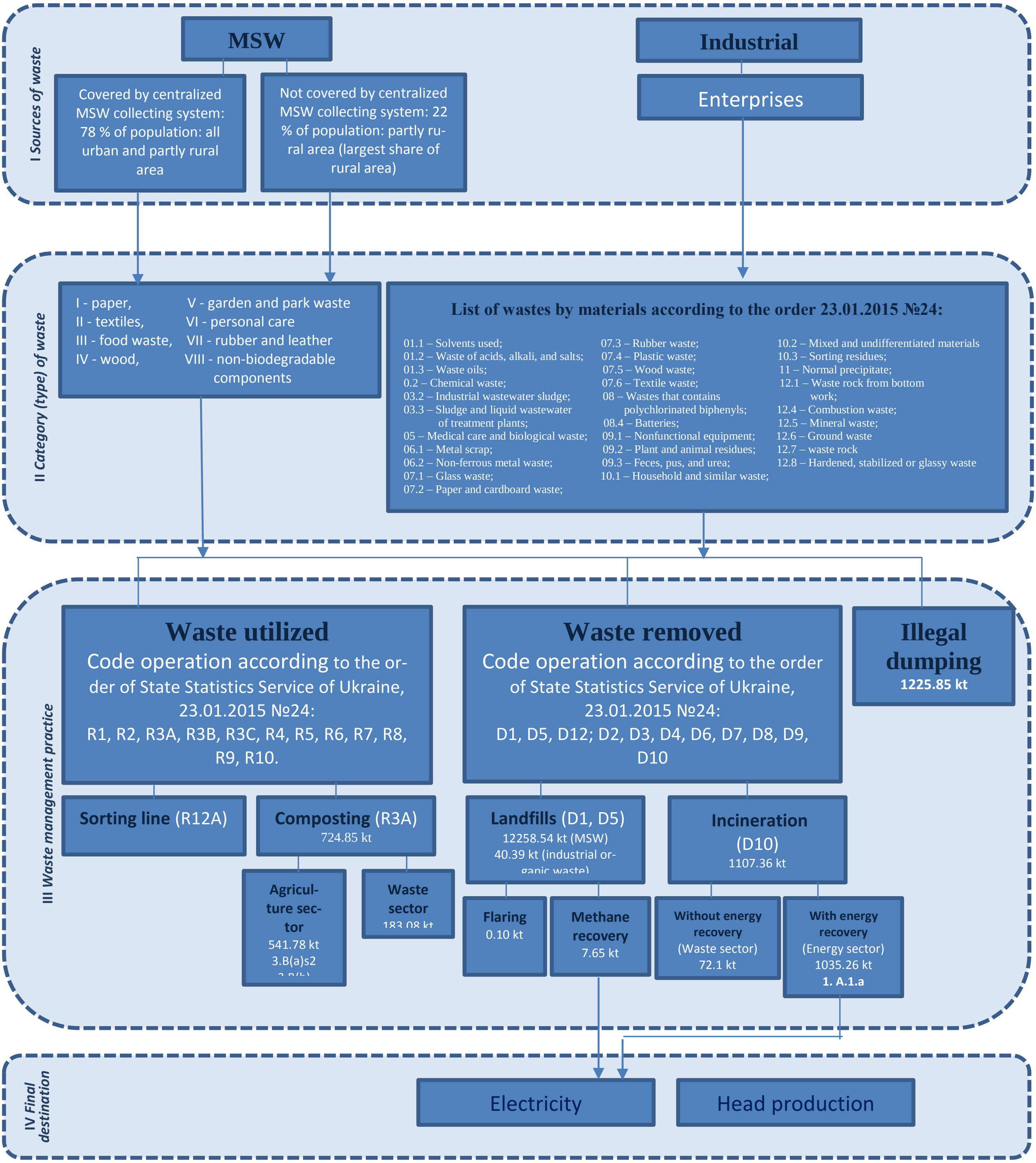


Fig. 7.3. Waste management practices in Ukraine, 2016

The entire array of data on the amount and distribution of solid waste by categories is presented in Annexes 3.4.1 and 3.4.2.

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[11] 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[2,] 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.

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 of 2010-2015, 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 1990-2016, see Table 7.3, on the amount of landfilled waste by different types of landfills in 1990-2016 – Annex 3, Table A3.4.1.

Table 7.3. 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

[11] 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.

Year	Dumps and landfills			MCF_{av}
	Unmanaged shal-low*	Unmanaged deep*	Managed*	
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

* - MSW shares disposed in dumps and landfills of different types

MSW composition (MWS_j), the content of biodegradable carbon (DOC_j), and the constant rate of methane production k_j. Paper [3] explores content of seven biodegradable components in MSW: paper and cardboard (I), textiles (II), food waste (III), wood (IV), garden and park waste (V), personal care products (VI), rubber and leather (VII) for the period of 1990-2013. It should be noted that the paper's [3] output includes exploration of MSW composition in 22 cities of Ukraine conducted in 2008-2013.

The MSW composition in Ukraine as a whole was calculated based on the amount of MSW landfilled in the regions, and missing source data - based on assumptions coordinated 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.

The MSW composition in 2014-2016 was adopted based on the data for 2013.

The model uses default *DOC* values for all the components to 2006 IPCC Guidelines [1].

In 2012, the field and laboratory experiments on DOC determination in food waste were carried out [12]. 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].

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.

Table 7.4 shows *kj* and *DOCj* data for MSW components used for inventory of methane emissions from MSW dumps and landfills.

Table 7.4. *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	Timber	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

For the more detailed composition of MSW in 1900-2016, see Fig. 7.4 and 7.5, as well as Table A3.4.2.

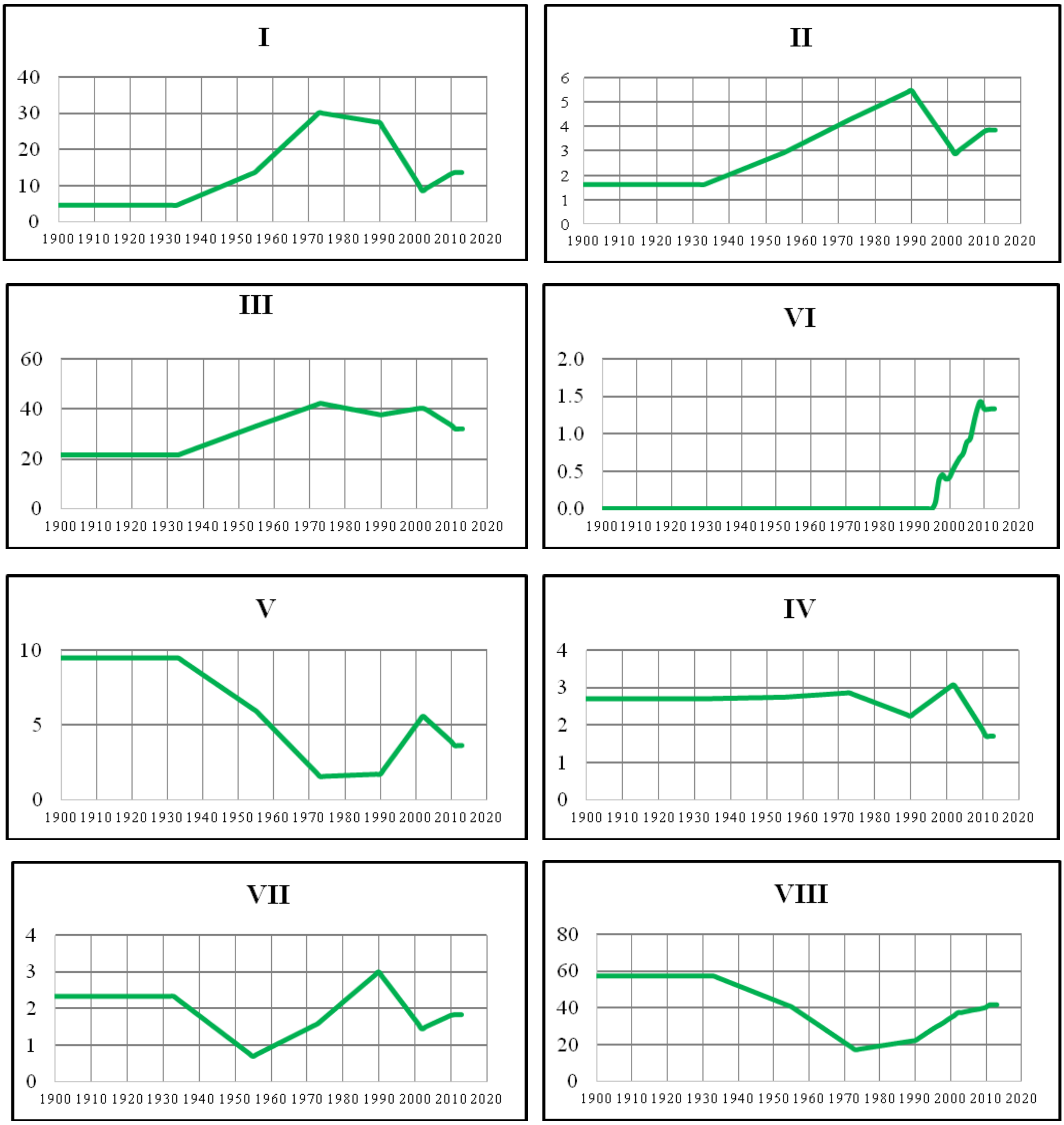


Fig. 7.4. Content of biodegradable MSW components for the period of 1900-2016, % to weight. For the meaning of I-VII, see Table 7.4.

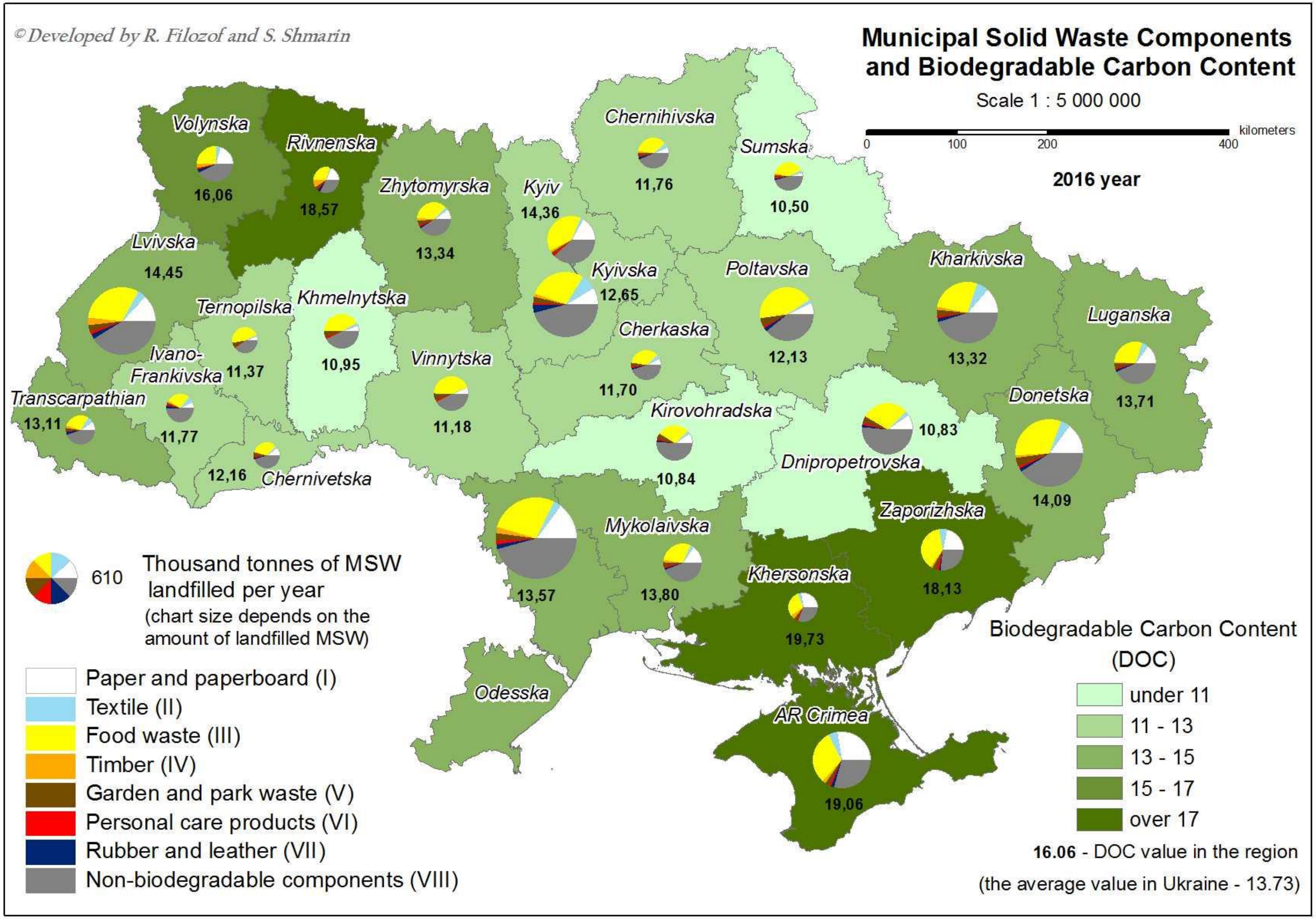


Fig. 7.5. The content of biodegradable components in the MSW composition, as well as the average DOC value in the regions of Ukraine, 2016

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 LLC "Alternative Environmental Protection Energy Systems and Technologies" commissioned the biogas collection systems at the landfills of the cities of Kremenchuk, Vynnytsya, and Zaporizhya.

In 2012, electricity was generated from landfill gas at the industrial scale for the first time in Ukraine. LLC "LNK" put into operation a biogas collection system with subsequent electricity generation at the MSW landfill in Kyiv, in 2013 - in the city of Boryspil, in 2014 - in the town of Brovary. Besides, in 2013 the degassing system at the landfill of Mariupil city was upgraded, as a result the extracted landfill gas began being used for electricity generation. In 2015, three landfill gas flaring facilities and six recovery ones were operated in Ukraine. In 2016, one landfill gas flaring facilities and seven recovery ones were operated in Ukraine.

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, m3;
ρ_{LG} - landfill gas density, kg/m3;
γ_m - methane content in landfill gas, % to weight.

According to the Guidelines [1], greenhouse gas emissions associated with methane recovery and subsequent production of electricity and heat are accounted for in the "Energy" sector.

Figure 7.6 shows the data on the amount of recycled methane in MSW dumps in Ukraine for the period of 2003-2016. Since 2008, this figure has been rising annually - from 0.15 tons to 13.37 tons in 2014. 11.72 kt of landfill methane was utilized in 2015 and 7.76 kt of landfill methane in 2016.

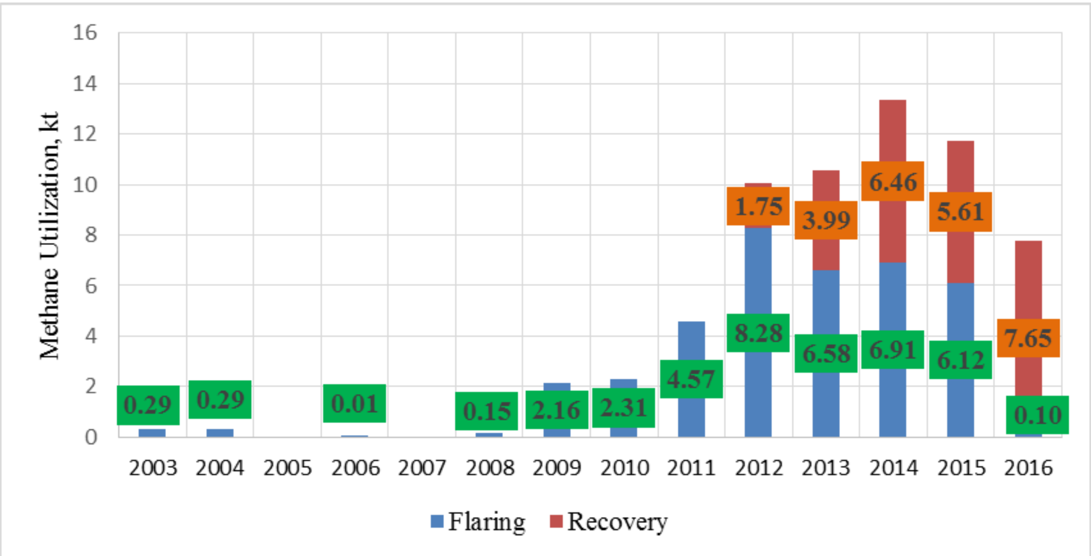


Fig. 7.6. Methane utilization at MSW landfills in Ukraine, 2003-2016

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:

$$DOCm\ LS_T = W_T \cdot DOC \cdot (1 - DOC_F) \cdot MCF, \quad (7.6)$$

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. 7.7 presents results of the estimations for the period of 1990-2016.

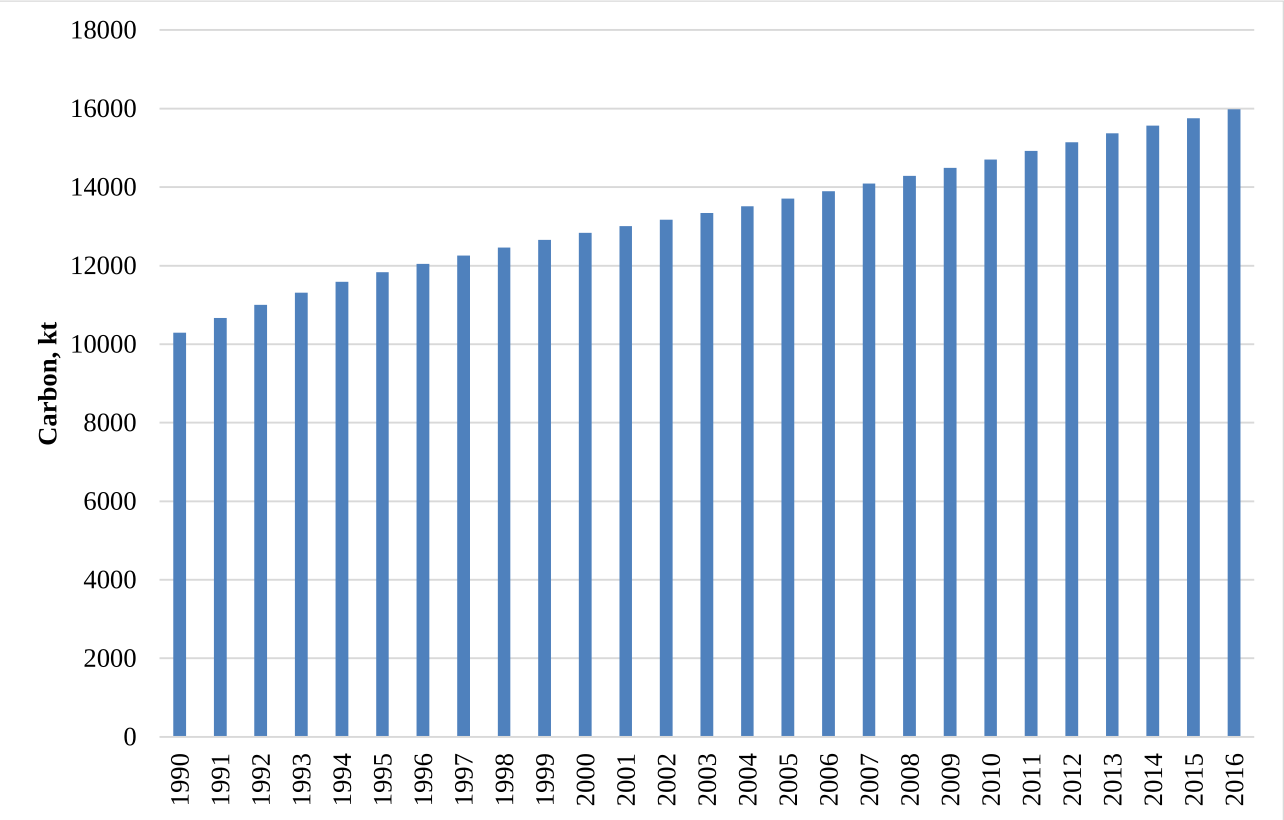


Fig. 7.7. Accumulated long-term storage carbon at MSW dumps, 1990-2016

7.2.3 Uncertainties and time-series consistency

The range of uncertainty estimates for activity data and emission factors was analyzed in paper [14] in accordance with [1]. See Table 7.5.

Table 7.5. The range of uncertainty estimates

Parameter	Estimated uncertainty	
	"-"	"+"
Activity data		
Mass of MSW dumped		
Managed landfills	*10*	*10*
Unmanaged landfills	*30*	*30*
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	47.17	47.17
Uncertainty of CH_4 emission factors for unmanaged deep landfills	41.53	41.53
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	**55.90**	**55.90**
The standard uncertainty of CH_4 emissions for unmanaged deep landfills	**51.23**	**51.23**

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, no recalculations were held.

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 2016 amounted to 34.68 kt of CO_2-eq., including: 0.73 kt of CH_4 and 0.06 kt of N_2O, the increase with respect to 1990 (34.36 kt of CO_2-eq.) is 0.9 % (see Fig. 7.8).

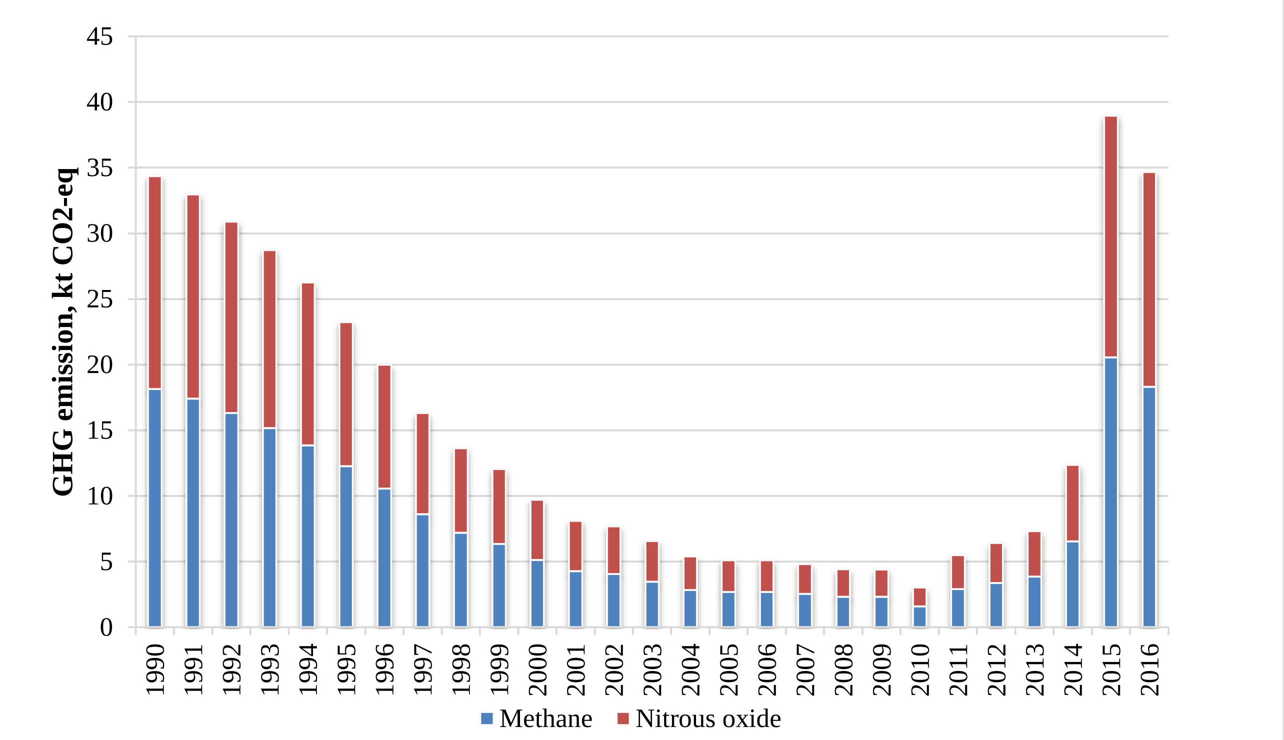


Fig. 7.8. GHG emissions from waste composting in Ukraine, 1990-2016.

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. Emissions reductions in 2016 compared to 2015 was caused by the decrease 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 [16-18]. 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 [19].

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):

$$Q_{CH_4} = M \cdot EF_{CH_4} \cdot 10^{-3} - R, \quad (7.7)$$

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;

$$Q_{N_2O} = M \cdot EF_{N_2O} \cdot 10^{-3}, \quad (7.8)$$

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 Regional 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" includes information about MSW composting, 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 composted waste (at the level) of enterprises is form "No.1 - waste", according to which the collection is held every year since 2010.

To estimate the volume of composted waste for GHG inventory, the entire set of primary source data at the enterprise level for the period of 2010-2016 was analyzed and processed.

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 thousand tons (74 enterprises), in 2011 - 196.0 thousand tons (91 enterprises), in 2012 -

310.6 thousand tons, in 2013 - 357.7 thousand tons (114 enterprises), in 2014 - 683.7 thousand tons (118 companies), in 2015 – 669,3 thousand tons (123 companies), in 2016 – 724,9 thousand tons .

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, and from the other categories - in the "Waste" sector.

Waste composting data on Table 7.6 presents data on waste composting in Ukraine based on results of *stage II* of raw data processing.

Table 7.6. Waste composting in Ukraine, 2010-2016, tons

Category	Designa-tion	DKV code	2010	2011*	2012*	2013	2014*	2015*	2016*
Bird droppings	I	0124.2.6.03	42107.8	62604.3	43307.2	60473.5	256610.3	15888.1	35946.73
Feces, pus, and urea	II	0121.2.6.03	89322.8	104411.3	233425.7	258515.7	361819.1	447706.9	505833.5
Plant residues (straw, etc.)	III	1583.1.1.02, 0111.3.1.01, 0111.2.9.02, 1561.2.9.04, 0112.2.9.01, 0112.3.1.02	3375.7	3734.1	2351.9	969.8	369.2	4937.4	746.2
Other vegeta-ble and animal residues	IV	0111.2.6.02, 1590.2.9.01, 0111.1.1.01, 0113.1.1.01, 1910.2.9.03	2301.2	3353.4	8553.4	13753.4	59944.5	154700.4	27868.9
Household and similar waste	V	5200.3.1.03, 1589.3.1.05	313.8	9993.8	6825.0	3656.2	17.2	3.6	36.39
Wood waste	VI	2000.2.2.17, 7760.3.1.03, 0113.2.9.01, 2000.2.2.16,	188.7	483.7	248.8	13.9	2874.4	6593.9	11336.6
Other waste	VII	1583.2.9.03, 9030.2.9.04, 7720.3.1.02, 1590.2.9.15, Other	9836.1	11412.0	15852.7	20293.5	2089.7	39422.4	143091.6
Total			**147446.2**	**195992.6**	**310564.8**	**357676.1**	**683724.7**	**669252.8**	**724859.9**

*Data of the State Statistic Service of Ukraine, corrected using analytical study

According to results of *phase III*, the time series of waste composting in Ukraine for categories I-VII for 1990-2009 was restored.

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.

To cover the whole territory of Ukraine, the analytical study [25] was used for 2014. In 2015 and 2016, for waste composted at temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol and for temporarily occupied territories of the Donetsk and Luhansk regions it was considered trends on wood harvest, MSW generation, crop residues and livestock.

Table 7.7. SW composting in Ukraine, 1990-2009

Year	Solid Waste Category								
	t								
	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 7.8, which corresponds to Table 4.1 of 2006 IPCC Guidelines [1].

Table 7.8. 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 7.9.

Table 7.9. 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 the current inventory, recalculations of CH_4 and N_2O emissions in the category were conducted for the period 1990-2009 and 2012 and were caused by the following factors:

- interpolation of waste composting data for 2012;
- clarification of livestock as a factor of extrapolation until 2009.

Results of the recalculation are provided in table 7.10.

Table 7.10. Recalculation in category 5.B "Biological Treatment of Solid Waste"

Year	Inventory Report, 2016 submission, Cg			Inventory Report, 2017 submission, Cg			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	-	0.542	0.041	-	0.726	0.054	-	33.94	33.94
1991	-	0.520	0.039	-	0.696	0.052	-	33.94	33.94
1992	-	0.487	0.037	-	0.652	0.049	-	33.94	33.94
1993	-	0.453	0.034	-	0.606	0.045	-	33.93	33.93
1994	-	0.414	0.031	-	0.554	0.042	-	33.94	33.94
1995	-	0.366	0.027	-	0.491	0.037	-	33.96	33.96
1996	-	0.315	0.024	-	0.422	0.032	-	33.97	33.97
1997	-	0.257	0.019	-	0.345	0.026	-	33.98	33.98
1998	-	0.215	0.016	-	0.288	0.022	-	33.98	33.98
1999	-	0.190	0.014	-	0.254	0.019	-	33.98	33.98
2000	-	0.153	0.011	-	0.205	0.015	-	33.99	33.99
2001	-	0.128	0.010	-	0.171	0.013	-	33.99	33.99
2002	-	0.121	0.009	-	0.162	0.012	-	33.98	33.98
2003	-	0.104	0.008	-	0.139	0.010	-	33.77	33.77
2004	-	0.085	0.006	-	0.114	0.009	-	33.47	33.47
2005	-	0.081	0.006	-	0.108	0.008	-	33.39	33.39
2006	-	0.081	0.006	-	0.108	0.008	-	33.40	33.40
2007	-	0.076	0.006	-	0.102	0.008	-	33.38	33.38
2008	-	0.070	0.005	-	0.093	0.007	-	33.34	33.34
2009	-	0.070	0.005	-	0.093	0.007	-	33.31	33.31
2010	-	0.064	0.005	-	0.064	0.005	-	-	-
2011	-	0.116	0.009	-	0.116	0.009	-	-	-
2012	-	0.025	0.002	-	0.135	0.010	-	451.77	451.77
2013	-	0.155	0.012	-	0.155	0.012	-	-	-
2014	-	0.261	0.020	-	0.261	0.020	-	-	-

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 have not been included in national total emission estimates. CO_2 emissions from oxidation during incineration of carbon in waste of fossil origin 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 1990–2016 is presented in Figure 7.9 and Table 7.11

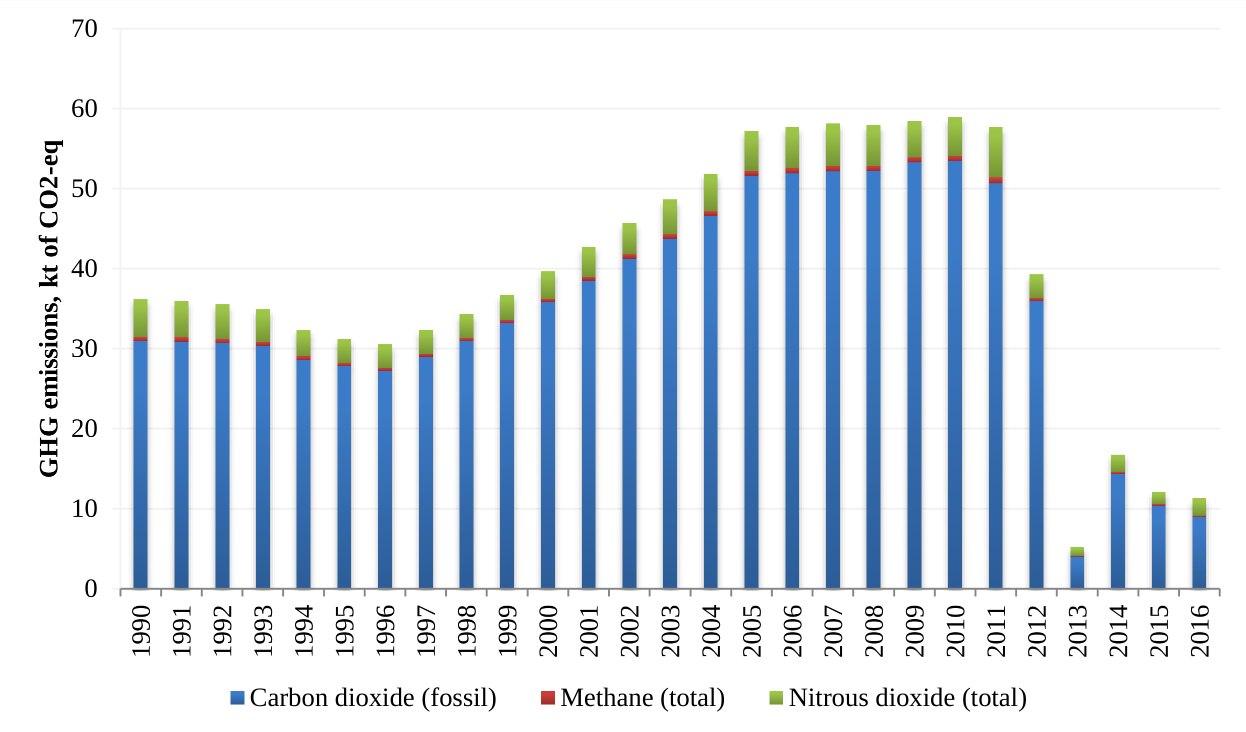


Fig. 7.9. GHG emissions from waste incineration without energy recovery in Ukraine, 1990-2016

Table 7.11. The amount of waste incinerated and GHG emissions from waste incineration in Ukraine, 1990-2016

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Waste incinerated with energy recovery, kt (Energy sector)	952.2	499.4	550.7	903.8	840.3	800.6	1082.9	883.1	873.5	1086.2	1035.3
Waste incinerated without energy recovery, kt (Waste sector), kt	201.2	138.7	156.4	221.1	218.1	253.9	133.0	35.6	75.04	49.8	72.1
CO_2 (Fossil), kt CO_2	30,92	27,83	35,84	51,63	53,47	50,70	35,96	4,05	14,35	10,44	8,98
CO_2 (Bio), kt CO_2	135,6	87,27	87,64	119,12	148,12	134,11	60,58	17,48	48,09	30,77	36,65
Total CH_4*, kt CH_4	0,024	0,016	0,019	0,026	0,026	0,030	0,016	0,004	0,009	0,006	0,009
Total N_2O*, kt N_2O	0,016	0,010	0,011	0,016	0,016	0,021	0,010	0,003	0,007	0,005	0,007

* not divided into biogenic and non-biogenic

GHG emissions from waste incineration without recovery of energy in 2016 amounted to 11.32 kt of CO_2-eq., including: CH_4 – 0.009 kt (0.21 kt of CO_2-eq.), N_2O – 0.007 kt (2.12 kt of CO_2-eq.), CO_2 – 8.98 kt. In the period from 1990 to 2016 the emissions decreased by 68.7 %.

Fig. 7.9 shows that in the period of 1990-1996, GHG emissions in this category decreased 1.2 times, which is due to a decrease in industrial production and MSW generation. Since 1997 and until 2007, GHG emissions steadily increased and reached 58.11 kt of CO_2-eq.The key factor in the GHG emission trends in 1997-2007 is a sharp increase in plastic content of MSW (from 9.4% to 12.0%) - the main source of CO_2 generation in the category. Besides, this period is characterized by a significant growth in industrial production and an increase in MSW formation. In 2007-2011, 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 2012 was due to closure at that time of one of the two operating waste incineration plants (WIP) in Dnipropetrovsk. The dramatic reduction of GHG emissions in 2013 was due to the fact that in that year the already only operating WIP (Kyiv) was subject to reconstruction. Nowadays to incinerate waste without energy recovery installations need special authorization documents.

In Ukraine, thermal treatment of waste outside specially designated equipped areas is prohibited by law, so official statistics do not consider an 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 the possibility of underestimation the regional authorities were officially asked about the existing situation on MSW treatment in private sector, as well as the lead experts were interviewed.

In order to establish the facts of unauthorized open burning of waste by the population were held expert meetings with profile specialists from all regional administrations. According to the results of the expert meetings, isolated cases of open burning were confirmed only in the Vinnytsia and Chernihiv oblasts. To estimate the maximum possible amount of GHG emissions from the burning of waste by the population of Vinnytsya and Chernihiv oblasts a conservative expert assessment was conducted.

The conservative estimate includes the following assumptions:

- specific MSW generation per person for the territory where there is no centralized waste collection are equal to those of the territory covered by centralized collection;

- all volumes of generated MSW in areas not covered by a centralized collection were burned and not included in the official statistics on the treatment of solid waste in the country;

- the composition of the generated MSW in uncovered centralized collection of rural areas 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 of Regional Development, Construction and Housing and Communal Services of Ukraine. Detailed data is provided in the Table. 7.12. The volumes of theoretically possible MSW combustion were 68.5 thousand tons.

Table 7.12. 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 7.13.

Table 7.13. Waste composition and waste amount which can be burned in Vinnytsia and Chernihiv oblasts, 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 was defined as the sum of fossil carbon content in each components provided in Table 7.13 and 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 thousand tons.

The maximum possible CO_2 emissions can be determined by the amount of fossil carbon burned. They amounted to 27.87 thousand tons. According to the Guideline, 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 thousand tons, and nitrous oxide N_2O emissions – 0.00758 thousand tons. Total maximum possible GHG emissions from open burning of solid waste equals 40.27 thousand tons 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 Ukraine's GHG emissions, so the corresponding emissions are insignificant and reported as "NE" in the CRF tables.

Therefore, the category accounts for 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 accounted for in the "Energy" sector.

7.4.2 Methodological issues

7.4.2.1 General principles

According to 2006 IPCC Guidelines [1], waste incineration means burning of solid and liquid waste at controlled incineration facilities. The waste includes MSW, industrial waste, hazardous waste, waste of health facilities, etc.

Emissions from waste incineration without energy recovery are accounted for in the "Waste" sector, while emissions from incineration with energy recovery are estimated in the "Energy" sector. These sectors separately account for CO_2 emissions from fossil and biogenic types of fuel *(DOC).*

According to [1], it is necessary to account for CO_2 net emissions and incorporate the data into the national estimate of the emissions of the respective gas only if CO_2 emissions were the result of oxidation processes during carbon incineration in waste of fossil origin (plastics, certain textiles, rubber, liquid solvents, waste oils, etc.).

CO_2 emissions from combustion of biomass (paper, food, wood waste) contained in waste are emissions from bioenergy and are not included into the general assessment of national emissions.

Waste incineration also results in emissions of CH_4 and N_2O.

Estimation of GHG emissions from waste incineration in the "Waste" sector is performed in accordance with the equations:

$$Q_{CO_2} = MSW \cdot \sum_j (WF_j \cdot dm_j \cdot CF_j \cdot FCF_j \cdot OF_j) \cdot 44/12, \quad (7.9)$$

Where: Q_{CO_2} is CO_2 emissions over the reporting year, thousand tons/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, thousand tons/year;
IW_j - amount of solid waste of type *i* (wet matter) subject to incineration or open burning, thousand tons;
EF_j - CH_4 emission component factor, kg of CH_4/thousand tons of waste;

10^{-6} - conversion factor kg to thousand tons;
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):

$$Q_{N_2O} = MSW \cdot \sum_i (IW_i \cdot EF_i) \cdot 10^{-6}, \qquad (7.11)$$

Where: Q_{N_2O} is N_2O emissions over the reporting year, thousand tons/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 Regional 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 Committee of Ukraine in accordance with form "No.1 - waste" is held annually since 2010. According to data of the State Statistics Committee of Ukraine, data on incineration of waste without energy generation are presented in Table 7.14.

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 [25] 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 seven sub-categories: paper and cardboard (IIa), rubber (IIb), plastic (IIc), wood (IId), textiles (IIe), and other (IIf)), as well as clinical waste (III).

Table 7.14. Waste incineration without energy generation in Ukraine in 2010-2016

Component*	Year						
	2010	2011	2012	2013	2014**	2015**	2016**
Solvents used	0.3	0.0	0.3	0.4	8.6	38.8	75.3
Waste of acids, alkali, and salts	5435.4	5366.1	7159.5	7912.8	4922.8	2072.8	4866.8
Waste oils	325.9	147.2	477.0	54.4	152.2	3152.5	3164.9
Used chemical catalysts	7.1	1.5	5.9	0.0	0.0	0	0.0
Used chemical products	584.8	740.5	560.2	1439.6	2199.8	349.7	450.6
Chemical deposits and residues	28314.3	44805.5	19997.5	3466.5	0.0	0	0.0
Residue of industrial effluents	52.9	7.6	12.7	10.7	331.8	1022.1	2717.6
Medical care and biological waste	405.6	45.0	265.6	75.9	500.0	445.0	1135.9
Metal scrap	4.2	0.5	0.0	0.2	18.5	0	0.0
Glass waste	1.7	1.0	0.0	1.2	1.3	2.0	1.7
Paper and cardboard waste	463.1	484.0	69.0	81.6	143.6	105.2	233.2
Rubber waste	20.1	124.0	114.4	57.8	53.2	27.7	87.2

Component*	Year						
	2010	2011	2012	2013	2014**	2015**	2016**
Plastic waste	172.2	31.0	11.6	87.7	2708.2	2110.0	607.6
Wood waste	49847.1	49011.8	10888.3	9407.8	27920.6	17887.2	20673.1
Textile waste	192.7	110.7	108.9	33.1	81.2	30.7	206.3
Wastes that contains polychlorinated biphenyls	103.0	0.3	10.2	0.0	0.0	0.0	0.0
Nonfunctional equipment	86.7	1390.9	78.2	19.0	9.3	8.8	20.8
Plant and animal residues	5090.3	51040.7	11593.7	6722.8	29539.8	19002.0	34970.4
Household and similar waste	126119.2	98897.9	78565.5	2911.0	3746.8	2110.3	2010.2
Mixed and undifferentiated materials	294.3	1415.1	1802.0	2510.6	2267.9	1149.6	658.3
Sorting residues	31.4	34.0	378.7	183.3	0.0	0	0.0
Normal precipitate	214.8	14.9	8.0	0.0	0.0	3.0	0.0
Waste rock from bottom reinforcement work	0.0	0.0	0.0	0.0	0.0	0	0.0
Mineral waste	279.6	202.8	892.7	526.3	241.4	231.4	169.9
Hardened, stabilized or glassy waste	45.5	5.6	37.9	58.9	189.2	10.6	50.8
Total	**218092.2**	**253878.6**	**133037.8**	**35561.6**	**75036.2**	**49759.4**	**72100.9**

*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

Results of *stage I* of raw data processing are shown in Table 7.15.

Table 7.15. MSW incineration without energy generation in Ukraine in line with the suggested waste classification, t, 2010-2016

Component	Designation	Element	Year						
			2010	2011	2012	2013	2014*	2015*	2016*
Municipal solid and similar waste	I	Household and similar waste	126119.2	98897.9	78565.5	2911.0	3746.8	2110.3	2010.2
Industrial	II	Of them:	91567.4	154935.7	54206.7	32574.7	70789.5	47204.0	68954.8
paper and cardboard	a	Paper and cardboard waste	463.1	484.0	69.0	81.6	143.6	105.2	233.2
rubber	b	rubber waste	20.1	124.0	114.4	57.8	53.2	27.7	87.2
plastic	c	Plastic waste	172.2	31.0	11.6	87.7	2708.2	2110.0	607.6
timber	d	Wood waste	49847.1	49011.8	10888.3	9407.8	27920.6	17887.2	20673.1
textile	e	Textile waste	192.7	110.7	108.9	33.1	81.2	30.7	206.3
other	f	Other	40872.2	105174.2	43014.5	22906.7	39882.5	27043.1	47147.4
Clinical waste	III	Medical care and biological waste	405.6	45.0	265.6	75.9	500.0	445.0	1135.9

*Data of the State Statistic Service of Ukraine, corrected using analytical study

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.
- When restoring the time series of 1990-2009, indicators of 2010 were taken as baseline values, that being the most comparable year.

To cover the whole territory of Ukraine, the analytical study [25] was used for 2014. In 2015 and 2016, for waste incinerated at temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol and for temporarily occupied territories of the Donetsk and Luhansk regions it was considered trends on MSW generation, quantity of surgical operations and energy consumption in “Energy” sector.

Estimation of the weight of waste incinerated without electricity production in Ukraine for the period of 1990-2009 is shown in Table 7.16.

Table 7.16. Waste incineration without energy generation in Ukraine in 1990-2009

Year	Waste category									MSW dumping	Plastic content of MSW, % of wet weight	Industrial production index, % to the previous year
	t									thousand tons		
	I	II	a	b	c	d	e	f	III			
1990	99886.0	101114.7	302.3	124.0	126.1	34136.0	147.7	66278.7	224.5	9872.9	6.9	99.9
1991	97476.7	96261.2	287.8	118.0	120.0	32497.4	140.6	63097.3	224.9	9634.7	7.2	95.2
1992	95018.6	90100.5	269.4	110.5	112.3	30417.6	131.6	59059.1	225.4	9391.8	7.6	93.6
1993	92425.9	82892.4	247.8	101.6	103.3	27984.2	121.1	54334.3	226.2	9135.5	8.0	92.0
1994	89187.5	60262.8	180.2	73.9	75.1	20344.5	88.0	39501.1	225.7	8815.4	8.4	72.7
1995	85446.3	53031.3	158.6	65.0	66.1	17903.2	77.5	34760.9	224.0	8445.6	8.7	88.0
1996	81591.9	50326.7	150.5	61.7	62.7	16990.1	73.5	32988.1	222.1	8064.7	9.1	94.9
1997	85723.5	50175.7	150.0	61.5	62.6	16939.1	73.3	32889.2	220.0	8473.0	9.4	99.7
1998	89852.5	49673.9	148.5	60.9	61.9	16769.7	72.6	32560.3	218.1	8881.1	9.7	99.0
1999	93863.3	51660.9	154.5	63.3	64.4	17440.5	75.5	33862.7	216.2	9277.6	10.1	104.0
2000	97722.0	58480.1	174.8	71.7	72.9	19742.7	85.4	38332.5	214.0	9659.0	10.5	113.2
2001	101402.5	66784.3	199.7	81.9	83.3	22546.1	97.6	43775.8	211.8	10022.8	10.8	114.2
2002	105000.8	71459.2	213.7	87.6	89.1	24124.4	104.4	46840.1	209.8	10378.4	11.3	107.0
2003	108931.3	82749.8	247.4	101.5	103.2	27936.0	120.9	54240.8	207.9	10766.9	11.3	115.8
2004	113015.0	93093.5	278.3	114.1	116.1	31428.0	136.0	61020.9	206.2	11170.6	11.5	112.5
2005	124868.4	95979.4	287.0	117.7	119.7	32402.3	140.2	62912.6	204.7	12342.2	11.7	103.1
2006	122362.0	101930.1	304.8	125.0	127.1	34411.2	148.9	66813.1	203.2	12094.4	11.9	106.2
2007	119855.7	109167.2	326.4	133.9	136.1	36854.4	159.5	71556.9	202.0	11846.7	12.0	107.1
2008	119722.5	103708.8	310.1	127.2	129.3	35011.7	151.5	67979.0	200.8	11833.5	12.1	95.0
2009	124935.3	82344.8	246.2	101.0	102.7	27799.3	120.3	53975.3	199.8	12348.8	12.3	79.4

7.4.2.3 Selection of emission factors

The composition of MSW in Ukraine is discussed in detail in Section 7.2. Average values of the factors according to [1] were used due to limited information on waste incineration parameters (Table 5.3,5.4, 2.4-2.6): the methane emissions factor for all types of waste - 118.5 g of CH_4/thousand tons of waste, for nitrous oxide - 100 g of N_2O/thousand tons of industrial waste, and 55,100 g of N_2O/thousand tons of MSW.

7.4.3 Uncertainties and time-series consistency

Uncertainty ranges were estimated in accordance with [1] and presented in Table 7.17.

Table 7.17. Uncertainty estimation ranges

	Estimated uncertainty	
	"-"	"+"
Activity data		
Mass of incinerated	31.03	31.03
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	**40.47**	**40.47**
Standard uncertainty of N_2O emissions	**104.70**	**104.70**
Standard uncertainty of CH_4 emissions	**104.70**	**104.70**

7.4.4 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.

7.4.5 Category-specific recalculations

In the current inventory, recalculations of CO_2, CH_4 and N_2O emissions in the category were conducted for the period 1990-2008 and 2014 and were caused by the following factors:

- clarification of the quantity of surgical operations for 2014;
- clarification of industrial production indexes as an extrapolation factor by the SSSU for different years during the period 1990-2009.

Results of the recalculation are provided in Table 7.18.

Table 7.18. Recalculation in category 5.C "Incineration and Open Burning of Waste "

Year	Inventory Report, 2016 submission, Cg			Inventory Report, 2017 submission, Cg			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
1990	34.469	0.029	0.020	30.921	0.024	0.016	-10.29	-18.54	-22.66
1991	34.247	0.028	0.019	30.891	0.023	0.015	-9.80	-18.25	-22.39
1992	33.348	0.026	0.018	30.705	0.022	0.014	-7.93	-15.54	-19.30
1993	31.828	0.023	0.015	30.359	0.021	0.013	-4.62	-9.75	-12.40
1994	28.664	0.018	0.011	28.598	0.018	0.011	-0.23	-0.56	-0.77
1995	27.889	0.017	0.010	27.832	0.016	0.010	-0.21	-0.53	-0.74
1996	27.313	0.016	0.010	27.258	0.016	0.010	-0.20	-0.53	-0.74
1997	29.072	0.016	0.010	29.017	0.016	0.010	-0.19	-0.52	-0.72
1998	31.013	0.017	0.010	30.959	0.017	0.010	-0.17	-0.50	-0.70
1999	33.282	0.017	0.010	33.226	0.017	0.010	-0.17	-0.50	-0.70

Year	Inventory Report, 2016 submission, Cg			Inventory Report, 2017 submission, Cg			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
2000	35.903	0.019	0.011	35.840	0.019	0.011	-0.18	-0.52	-0.73
2001	38.592	0.020	0.012	38.520	0.020	0.012	-0.19	-0.55	-0.76
2002	41.383	0.021	0.013	41.305	0.021	0.013	-0.19	-0.57	-0.77
2003	43.853	0.023	0.014	43.763	0.023	0.014	-0.21	-0.60	-0.81
2004	46.708	0.025	0.016	46.607	0.024	0.016	-0.22	-0.63	-0.83
2005	51.734	0.026	0.017	51.630	0.026	0.016	-0.20	-0.61	-0.81
2006	52.058	0.027	0.017	51.947	0.027	0.017	-0.21	-0.63	-0.84
2007	52.366	0.027	0.018	52.207	0.027	0.018	-0.30	-0.89	-1.16
2008	52.368	0.027	0.017	52.234	0.027	0.017	-0.26	-0.77	-1.01
2009	53.335	0.025	0.015	53.335	0.025	0.015	-	-	-
2010	53.471	0.026	0.016	53.471	0.026	0.016	-	-	-
2011	50.698	0.030	0.021	50.698	0.030	0.021	-	-	-
2012	35.961	0.016	0.010	35.961	0.016	0.010	-	-	-
2013	4.047	0.004	0.003	4.047	0.004	0.003	-	-	-
2014	14.328	0.009	0.007	14.345	0.009	0.007	0.12	0.16	0.16

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.

GHG emissions in this category in 2016 amounted to 4,087.78 kt CO_2-eq. (32.6 % of total GHG emissions in the "Waste" sector), having decreased with respect to 1990 (5,318.44 kt CO_2-eq.) by 23.14 %.

GHG emissions from treatment of industrial sewage amounted to 923.64 kt CO_2-eq. (22.60 % of the category), of methane from domestic sewage - 2,124.09 thousand tons of CO_2-eq (51.96 % of the category), and of nitrous oxide from human life activity sewage – 1,040.05 kt CO_2-eq. (25.44 % of the category). Dynamics of GHG emissions at wastewater treatment is presented in Fig. 7.10.

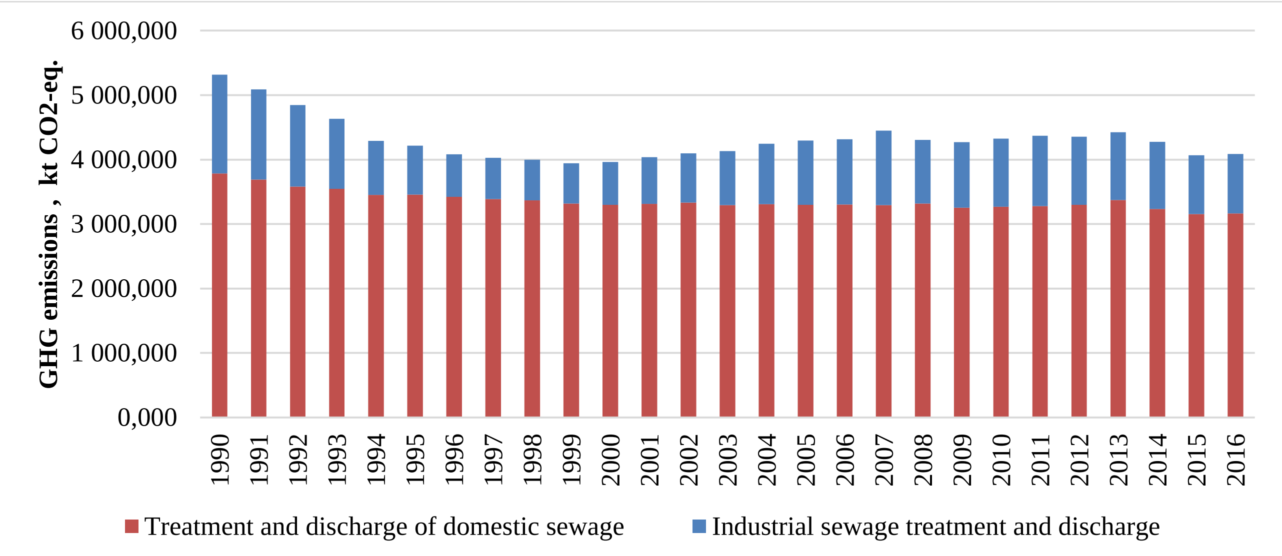


Fig. 7.10. Greenhouse gas emissions from waste water treatment in Ukraine, 1990-2016

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 2,124.09 kt CO_2-eq (84.96 kt CH_4) in 2016. The reduction in emissions relative to 1990 (2,212.06 kt CO_2-eq) constituted 3.97 %, compared to 2015 – increasing by 0.93 % (Fig. 7.11).

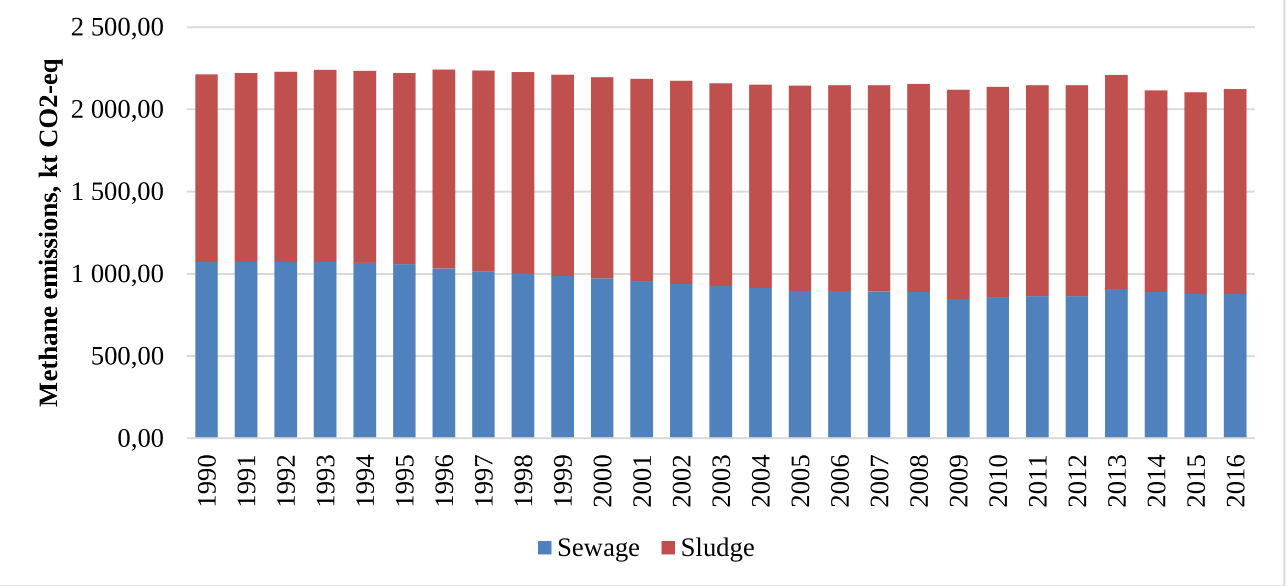


Fig. 7.11. Methane emissions from domestic sewage and sludge treatment in Ukraine, 1990-2016

In general, the annual fluctuation in GHG emissions in this sub-category is the smallest compared with the other emission sources in the "Waste" sector. It should be noted that the decrease in GHG emissions in 2016 compared with 1990 of 3.98 % was due to decrease of population of Ukraine, and the subsequent increase in emissions in 2016 by 0.93 % compared to 2015 was due to increase of centralized water treatment in households.

The structure of the drainage system of domestic wastewater is shown in the Fig. 7.12

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" [20].

Methane emissions from domestic wastewater treatment were determined under formula [20].

$$E_{CH4} = 365 \times \sum_k P \times q_{BOD} \times F_k \times B_0 \qquad (7.12)$$

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. 7.16);

$B_0 = 0.6$ - maximum methane production capacity, kg of CH_4/kg of BOD [1].

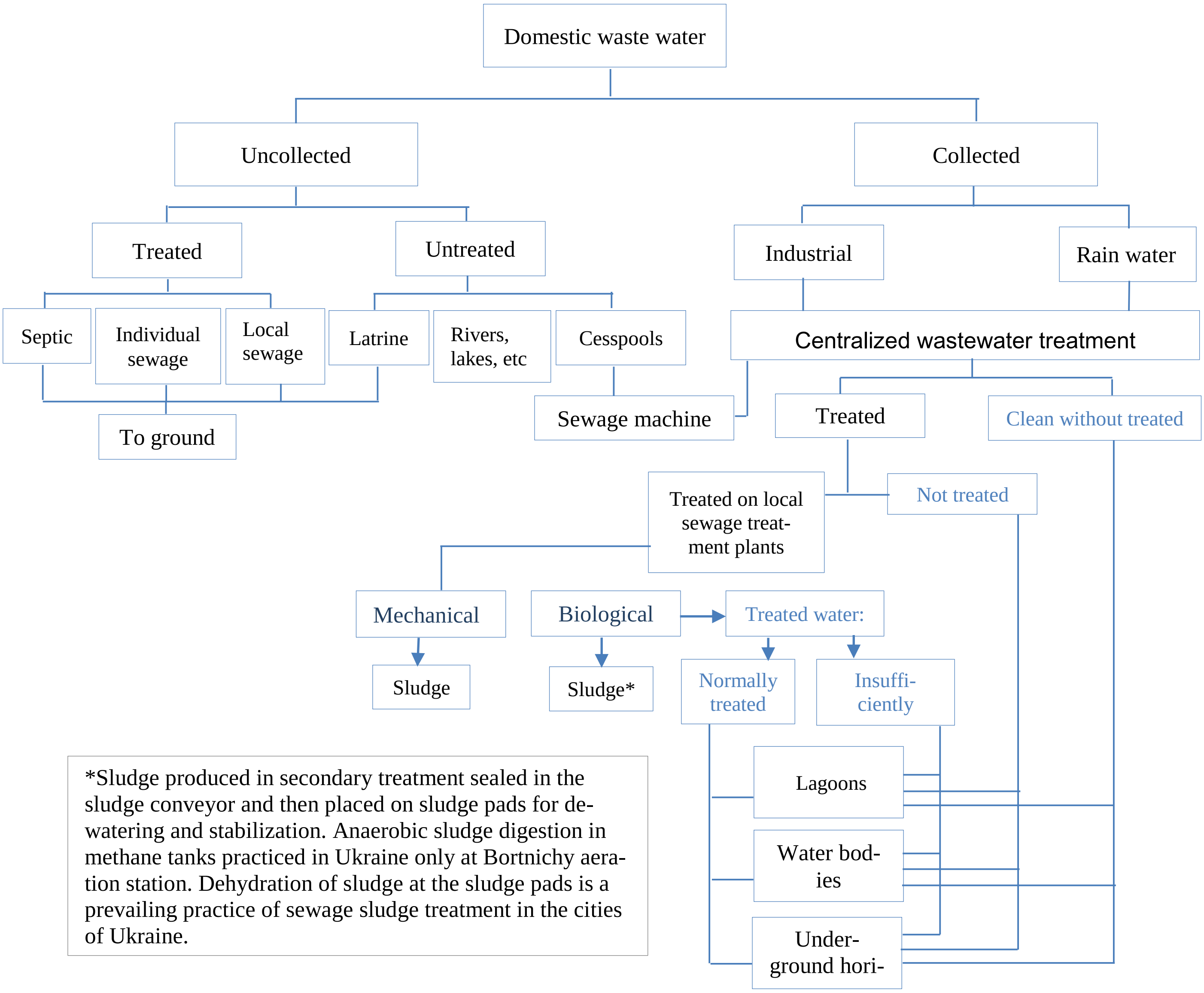


Figure 7.12 The structure of the drainage system of domestic wastewater

7.5.2.2.2 Activity data

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 7.19) 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).

Table 7.19. The degree of application of domestic sewage treatment and discharge systems in Ukraine, 1990-2016

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	45.77	34.10	8.25	22.62	3.22	11.67	0.11	11.56	54.23
1991	45.99	34.26	8.52	22.56	3.18	11.73	0.12	11.61	54.01
1992	46.27	34.47	8.82	22.51	3.14	11.80	0.13	11.67	53.73
1993	46.41	34.58	9.10	22.38	3.09	11.84	0.14	11.69	53.59
1994	46.44	34.59	9.38	22.19	3.02	11.84	0.16	11.69	53.56
1995	46.59	34.71	9.70	22.05	2.96	11.88	0.17	11.71	53.41
1996	48.85	36.39	10.20	23.13	3.07	12.46	0.21	12.25	51.15
1997	49.72	37.04	10.67	23.32	3.04	12.68	0.23	12.46	50.28
1998	50.35	37.50	11.12	23.39	3.00	12.84	0.24	12.60	49.65
1999	50.64	37.73	11.52	23.28	2.93	12.92	0.26	12.66	49.36
2000	50.99	37.98	11.96	23.17	2.85	13.01	0.28	12.73	49.01
2001	51.83	38.61	12.55	23.27	2.79	13.22	0.30	12.92	48.17
2002	52.38	39.02	13.11	23.20	2.71	13.36	0.33	13.03	47.62
2003	52.64	39.21	13.64	22.98	2.60	13.43	0.36	13.06	47.36
2004	53.19	39.63	14.29	22.84	2.49	13.57	0.40	13.17	46.81
2005	54.12	40.32	15.56	22.30	2.45	13.80	0.47	13.34	45.88
2006	54.38	40.51	15.86	22.62	2.03	13.87	0.65	13.22	45.62
2007	55.12	41.06	16.35	22.54	2.18	14.06	0.82	13.24	44.88
2008	56.09	41.78	18.48	21.43	1.89	14.31	1.19	13.12	43.91
2009	57.18	42.60	27.49	13.46	1.64	14.58	1.62	12.96	42.82
2010	57.96	43.18	28.79	12.93	1.46	14.78	2.12	12.66	42.04
2011	58.98	43.94	30.93	11.72	1.29	15.04	2.58	12.46	41.02
2012	59.50	44.33	32.39	10.22	1.70	15.18	2.87	12.31	40.50
2013	60.08	44.76	26.80	16.76	1.19	15.32	3.13	12.19	39.92
2014	57.20	42.61	33.27	8.38	0.96	14.59	3.25	11.34	42.80
2015	58.80	43.80	35.01	7.19	1.61	15.00	3.54	11.46	41.20
2016	59.20	44.10	34.83	8.37	0.90	15.10	3.71	11.39	40.80

Table 7.20. Amount of BOD_5 in domestic waste water treated in any way in Ukraine, 1990-2016

	Flows of BOD from DWW, thousand tons of BOD_5/day								Latrines, thousand tons of BOD_5/day	Total, thousand tons 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	1.4056	2.5919
1991	1.1944	0.8897	0.2213	0.5858	0.0826	0.3046	0.0030	0.3016	1.4028	2.5972
1992	1.2042	0.8971	0.2295	0.5859	0.0818	0.3072	0.0033	0.3038	1.3986	2.6028
1993	1.2124	0.9032	0.2378	0.5847	0.0807	0.3092	0.0038	0.3055	1.3998	2.6122
1994	1.2101	0.9014	0.2444	0.5782	0.0788	0.3086	0.0041	0.3045	1.3957	2.6057
1995	1.2050	0.8977	0.2508	0.5702	0.0767	0.3074	0.0045	0.3029	1.3814	2.5864
1996	1.2528	0.9333	0.2615	0.5931	0.0786	0.3195	0.0054	0.3142	1.3120	2.5649
1997	1.2633	0.9411	0.2711	0.5926	0.0773	0.3222	0.0057	0.3165	1.2776	2.5409
1998	1.2680	0.9446	0.2800	0.5891	0.0755	0.3234	0.0061	0.3174	1.2506	2.5185
1999	1.2640	0.9416	0.2875	0.5810	0.0730	0.3224	0.0064	0.3160	1.2319	2.4959
2000	1.2602	0.9388	0.2956	0.5727	0.0704	0.3214	0.0068	0.3146	1.2113	2.4715
2001	1.2680	0.9446	0.3071	0.5693	0.0683	0.3234	0.0075	0.3160	1.1782	2.4462
2002	1.2690	0.9454	0.3177	0.5621	0.0656	0.3237	0.0081	0.3156	1.1538	2.4229
2003	1.2635	0.9412	0.3275	0.5515	0.0624	0.3223	0.0088	0.3135	1.1367	2.4002
2004	1.2666	0.9435	0.3403	0.5439	0.0593	0.3231	0.0095	0.3135	1.1145	2.3811
2005	1.2795	0.9531	0.3679	0.5272	0.0580	0.3263	0.0110	0.3153	1.0846	2.3640
2006	1.2761	0.9506	0.3720	0.5307	0.0477	0.3255	0.0152	0.3103	1.0704	2.3465
2007	1.2856	0.9577	0.3814	0.5256	0.0507	0.3279	0.0190	0.3089	1.0467	2.3323
2008	1.3005	0.9688	0.4284	0.4968	0.0439	0.3317	0.0275	0.3042	1.0181	2.3186
2009	1.3193	0.9828	0.6341	0.3106	0.0379	0.3365	0.0374	0.2991	0.9879	2.3072
2010	1.3320	0.9923	0.6616	0.2971	0.0335	0.3397	0.0487	0.2910	0.9661	2.2981
2011	1.3448	1.0018	0.7052	0.2671	0.0294	0.3430	0.0588	0.2842	0.9351	2.2799
2012	1.3620	1.0146	0.7413	0.2340	0.0389	0.3474	0.0657	0.2817	0.9269	2.2889
2013	1.3684	1.0194	0.6104	0.3817	0.0270	0.3490	0.0713	0.2777	0.9092	2.2777
2014	1.2993	0.9679	0.7557	0.1904	0.0218	0.3314	0.0738	0.2576	0.9721	2.2714
2015	1.3199	0.9832	0.7859	0.1614	0.0362	0.3366	0.0794	0.2573	0.9248	2.2447
2016	1.3244	0.9866	0.7792	0.1872	0.0201	0.3378	0.0830	0.2548	0.9128	2.2371

Generation of BOD_5 per capita daily was taken as 50 g/pers./day as the national factor on the basis of [20] with regard to the current state sanitary regulations [21]. BOD flows are presented in Table 7.20.

To cover the whole territory of Ukraine, the analytical study [25] was used for 2014. In 2016, for water treatment at temporary occupation of the Autonomous Republic of Crimea and the city of Sevastopol was used information about population according to the data of the Russian occupation administration.

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*, at treatment of domestic wastewater are defined in accordance with [20] and presented in Table 7.21. When estimating *BOD* flows, the efficiency of their removal at processing with each of the methods is considered, adopted in accordance with [22].

Biodegrable parts of sewage BOD of different BOD flows were calculated based on the formulas [20]:

$$F_{tr} = E_{BOD.tr} \times MCF_{tr} + (100 - E_{BOD.tr}) \times MCF_w, \quad (7.13)$$
$$F_{ins.tr} = E_{BOD.ins.tr} \times MCF_{ins.tr} + (100 - E_{BOD.ins.tr}) \times MCF_w, \quad (7.14)$$
$$F_{not.tr} = MCF_w, \quad (7.15)$$
$$F_{sept} = MCF_{sept}, \quad (7.16)$$
$$F_{cessp} = (F_{tr} + F_{ins.tr})/2, \quad (7.17)$$
$$F_{latr} = MCF_{latr}, \quad (7.18)$$

where $E_{BOD.tr} = 0.9164$ - efficiency of BOD removal for treated wastewater [20];

$E_{BOD.ins.tr} = 0.84$ - efficiency of BOD removal for insufficiently treated wastewater [20];

$MCF_{tr}, MCF_{ins.tr}, MCF_{sept}, MCF_{latr}$ - conversion factor MCF for different BOD flows (tabl. 7.16);

$MCF_w = 0.1$ - conversion factor MCF for water reservoirs [1].

Biodegradable parts of sludge BOD of different BOD flows were calculated based on the formulas [20]:

$$F_{sl.tr} = (E_{BOD.tr} - F_{aer.tr}) \times MCF_{UA}, \quad (7.19)$$
$$F_{sl.ins.tr} = (E_{BOD.ins.tr} - F_{aer.ins.tr} - MCF_{ins.tr}) \times MCF_{UA}, \quad (7.20)$$
$$F_{sl.cessp} = \left(F_{sl.tr} + F_{sl,ins.tr}\right)/2, \quad (7.21)$$

where $F_{aer.tr} = 0.3$ - biomass growth rate under aerobic treatment (expert estimation) [20];

$F_{aer.ins.tr} = 0.15$ – full sludge BOD removal under aerobic treatment (expert estimation) [20];

$MCF_{UA} = 0{,}299$ – especial conversion factor MCF for Ukraine [20].

Table 7.21. 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
	Treated at the standard level	Insufficiently treated	Not treated	Septic tanks	Cesspools	
MCF	0	0.05	0.1	0.5	0.1	0.1
Biodegradable part of sewage BOD	0.0083	0.0580	0.1	0.5	0.0332	0.1
Biodegradable part of sludge BOD	0.1844	0.1914	0	0	0.1879	0

The value of the MCF_{UA} factor for sludge dehydration systems was estimated for the specific conditions of sewage sludge treatment in Ukraine. The dominant practice of sludge treatment in Ukraine is their dehydration/drying on sludge beds in the climate conditions of the region throughout the year. Therefore, when estimating emissions of methane from sewage sludge, the unified weighted average value of the national *BOD* to methane conversion factor, MCF_{UA}, is used, determined in accordance with the *ACM0014* methodology [23]. Given the fact that the average depth of sludge beds in Ukraine is from 1 to 2 m, and the frequency of discharge of dried sludge is once a year, MCF_{UA} is 0.299 [20].

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 [20] (Table 7.22).

Table 7.22. 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	21.45	21.45
Uncertainty of emission factors	36.88	36.88
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 was fixed a mistake under calculation of population of temporary occupied the Autonomous Republic of Crimea and the city of Sevastopol in 2015. Also was improved calculation of the degree of application of sewage treatment or discharge systems by approximation of the data of Ukraine on temporary occupied the Autonomous Republic of Crimea and the city of Sevastopol in 2015.

Results of recalculation are provided in Table 7.23.

Table 7.23. Recalculation in subcategory 5.D.1.1 "Methane emissions from domestic wastewater treatment"

Year	Inventory Report, 2017 submission, kt			Inventory Report, 2018 submission, kt			Difference, %		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
2015	-	84.86	-	-	84.96	-	-	0,12	-

7.5.2.6 Category-specific planned improvements

In this sub-category, no improvements are planned.

7.5.3 Nitrous Oxide Emissions from Human Waste Water (CRF category 5.D.1.2)

7.5.3.1 Category description

Nitrous oxide emissions from sewage of domestic wastewater amounted to 1040.05 kt CO_2-eq. in 2016 (3.49 kt), and their reduction with respect to 1990 (1,570.15 kt CO_2-eq.) is 33.76 %.

In 2016, consumption (gross) of protein per capita per day was 82.18 g/person/day (actual consumption), including: of vegetable origin - 41.03 g/person/day, of animal origin - 41.15 g/person/day. Information on emissions in the category for the period of 1990-2016 is shown in Fig. 7.13.

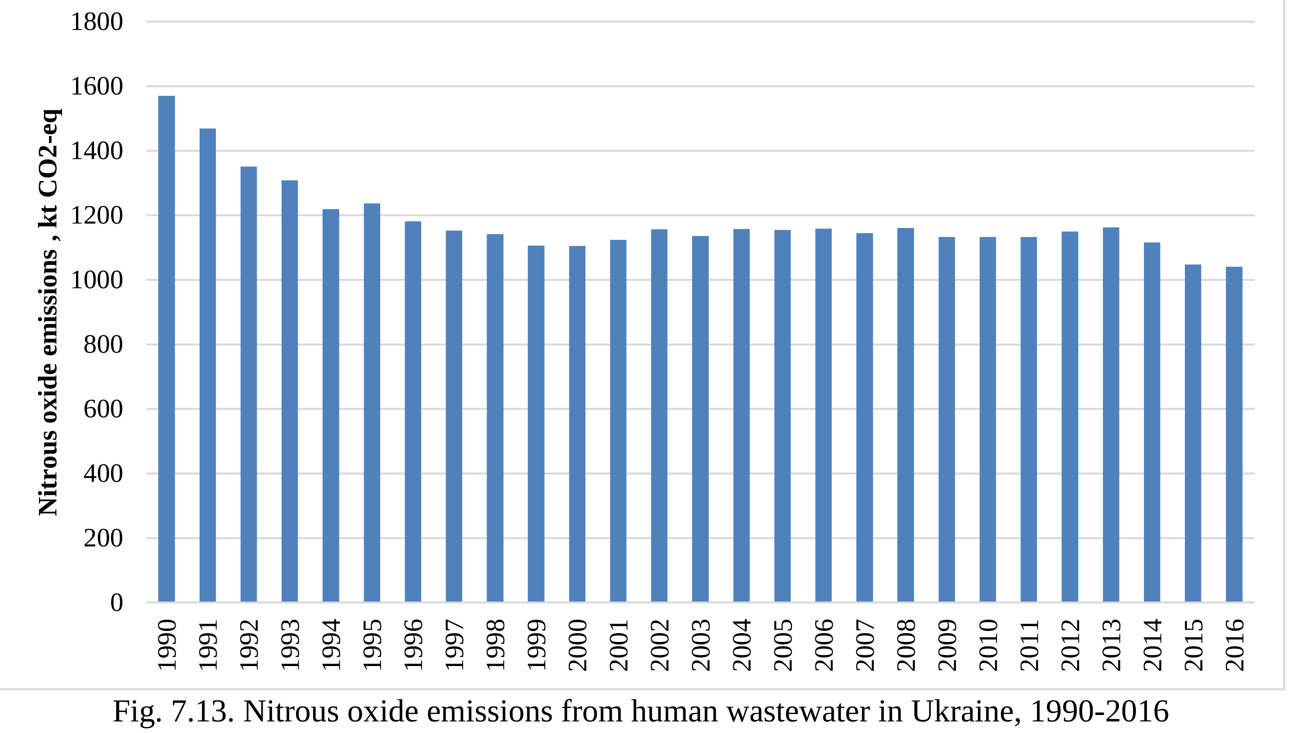


Fig. 7.13. Nitrous oxide emissions from human wastewater in Ukraine, 1990-2016

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 was divided on: indirect N_2O emissions and direct N_2O emissions. GHG emissions were calculated based on the formulas:

$$N_2O_i = N_{effluent} \times E_{f.effluent} \times 44/28, \quad (7.22)$$

$$N_2O_d = P \times T_{plant} \times F_{ind-comm} \times E_{f.plant} \times 10^{-8}, \quad (7.23)$$

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 1990-2016 is shown in Table 7.24.

Table 7.24. Indirect and direct N_2O emissions in Ukraine in 1990-2016

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	8,25	0,01
1991	1787,76	314,65	4,94	52000,50	8,52	0,01
1992	1644,11	289,36	4,55	52150,35	8,82	0,01
1993	1593,23	280,41	4,41	52179,25	9,10	0,02
1994	1484,64	261,30	4,11	51921,40	9,38	0,02
1995	1507,06	265,24	4,17	51512,75	9,70	0,02
1996	1439,22	253,30	3,98	51057,75	10,20	0,02
1997	1405,08	247,29	3,89	50594,60	10,67	0,02
2001	1370,87	241,27	3,79	48690,15	12,55	0,02
2002	1410,95	248,33	3,90	48230,30	13,11	0,02
2003	1385,98	243,93	3,83	47812,95	13,64	0,02
2004	1412,78	248,65	3,91	47451,60	14,29	0,02
2005	1409,22	248,02	3,90	47105,15	15,56	0,02
2006	1413,84	248,84	3,91	46787,75	15,86	0,02
2011	1390,29	244,69	3,85	45706,05	30,93	0,05
2012	1412,31	248,57	3,91	45593,30	32,39	0,05
2013	1424,54	250,72	3,94	45489,60	26,80	0,04
2014	1371,73	241,42	3,79	45318,67	33,27	0,05
2015	1289,54	226,96	3,57	45156,20	35,01	0,05
2016	1280,05	225,29	3,54	45004,67	34,83	0,05

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 Committee 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.

To cover the whole territory of Ukraine, the analytical study [25] was used for 2014. In 2016, for food consumed at temporary occupied the Autonomous Republic of Crimea and the city of Sevastopol and for temporarily occupied territories of the Donetsk and Luhansk regions it was considered trends on population growth.

Consumption of certain food product groups in Ukraine in 1990-2016 is shown in Table 7.25.

Table 7.25. Consumption of main food-stuffs of the population on Ukraine, 1990-2016

Food products	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014***	**2015***	**2016***
	thousand tons										
Animal origin											
Meat and meat products, including sub-products and raw fat	3536.7	2002.0	1611.0	1843.9	2384.0	2339.4	2478.0	2550.0	2400.4	2246.1	2264.1
Milk and dairy products	19363.4	12548.5	9788.8	10625.1	9363.0	97971.1	10050.0	9581.1	9825.1	9273.4	9223.5
Eggs (1 pc.)	14137.9	8824.9	8142.1	11207.0	13279.6	14165.0	14019.6	14075.8	13738.6	12386.7	11768.3
Fish and fish products	907.0	187.5	412.5	676.5	667.0	614.3	620.1	662.5	498.9	378.6	423.1
Vegetable origin											
Potato	6799.8	6376.4	6660.2	6385.6	5913.8	6368.3	6393.9	6160.6	6227.1	6073.8	6154.1
Vegetables and melon food crops	5318.8	4978.8	5002.0	5662.5	6581.3	7440.0	7452.2	7430.5	7225.8	7103.0	7204.0
Grain products	7314.3	6616.6	6141.0	5817.2	5105.9	5046.8	4989.9	4933.2	4812.8	4559.7	4444.3
Fruits, berries, and grape (without processing as wine)	2459.6	1720.9	1439.1	1749.6	2203.2	2405.0	2432.3	2560.1	2320.1	2246.3	2185.4
Sugar	2592.8	1627.1	1809.0	1794.6	1704.0	1758.3	1713.4	1686.0	1606.1	1575.2	1465.1
Oils	600.6	423.1	461.4	635.0	680.0	625.3	590.5	603.5	577.8	541.4	513.0

*Data of the State Statistic Service of Ukraine, corrected using analytical study

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 Committee 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].

In the current inventory, the $F_{NON\text{-}CONl}$ factor (f. 7.13) for the first time 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 [12] explores the composition of food waste as an MSW component, that also are well correlated with historical data [10,13], 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 [12]:

$$F_{NON\_CON_l} = MWS \cdot MWS_j \cdot B_l / P_{вал_l} \cdot 10^3; \qquad (7.14)$$

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 [12], 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 7.26.

Table 7.26. 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		
Food consumption, thousand tons	5	6.39
Uncertainty of activity data	5	6.39
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)[12] 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. 7.14.

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.

[12] http://faostat3.fao.org/faostat-gateway/go/to/download/FB/FB/E

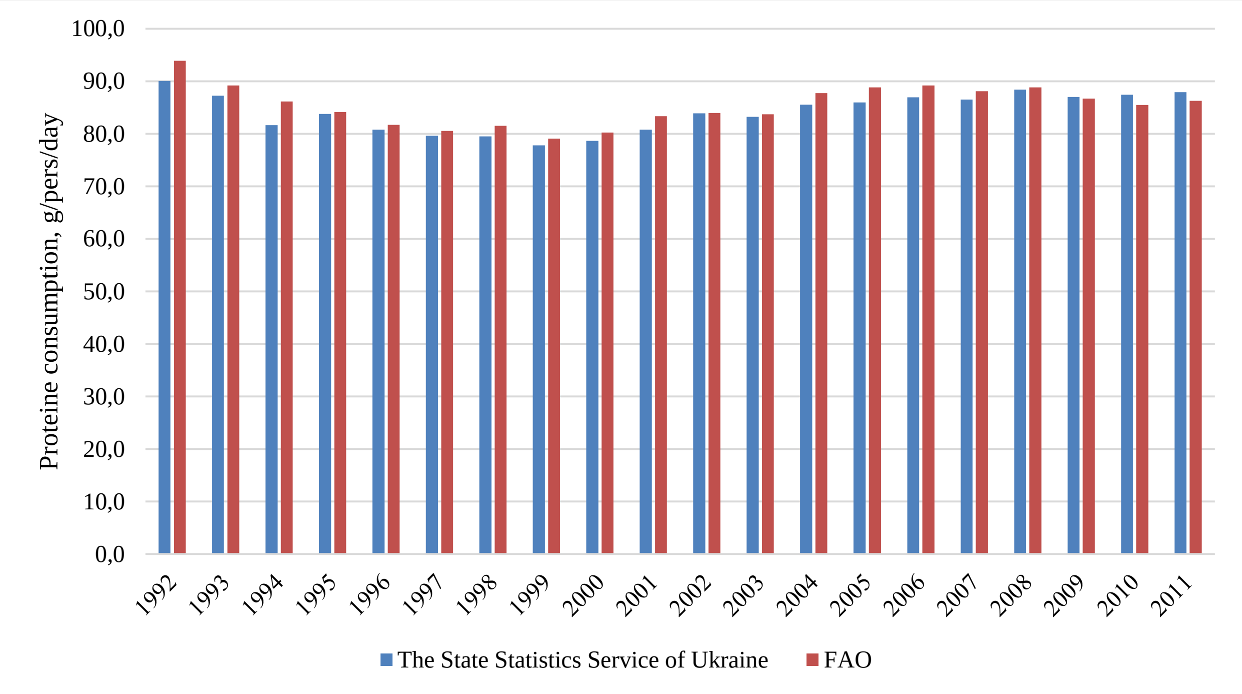


Fig. 7.14. Consumption of protein by the population of Ukraine, 1992-2011: columns on the left - the State Statistics Service of Ukraine, on the right – FAO

7.5.3.5 Category-specific recalculations

Recalculation was made under estimation of indirect and direct N_2O emissions. Results of recalculation are provided in Table 7.27.

Table 7.27. Recalculation in subcategory 5.D.1.2 "Nitrous Oxide Emissions from Human Waste Water"

Year	**Inventory Report, 2017 submission, kt**	**Inventory Report, 2018 submission, kt**	**Difference, %**
1990	5,27	4,80	9,71
1991	4,93	4,49	9,68
1992	4,53	4,13	9,64
1993	4,39	4,01	9,62
1994	4,09	3,73	9,58
1995	4,15	3,79	9,58
1996	3,96	3,62	9,54
1997	3,87	3,53	9,51
1998	3,83	3,50	9,49
1999	3,71	3,39	9,46
2000	3,71	3,39	9,44
2001	3,77	3,45	9,43
2002	3,88	3,55	9,43
2003	3,81	3,48	9,40
2004	3,89	3,55	9,39
2005	3,87	3,54	9,34
2006	3,89	3,55	9,33
2007	3,84	3,51	9,31
2008	3,90	3,57	9,23
2009	3,80	3,49	8,84
2010	3,80	3,49	8,79
2011	3,80	3,50	8,71
2012	3,86	3,55	8,67
2013	3,90	3,58	8,91
2014	3,75	3,45	8,60
2015	3,52	3,24	8,44
2016	3,49	3,22	8,44

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 2016 GHG emissions from treatment of industrial wastewater amounted to 923.64 kt CO_2-eq., the decrease with respect to 1990 (1,536.23 kt CO_2-eq.) is 39.9 % (see Fig. 7.14). Of these, methane emissions - 861.09 kt CO_2-eq. (34.44 kt), nitrous oxide - 62.55 kt CO_2-eq. (0.210 kt).

Due to ongoing military aggression of the Russian Federation against Ukraine, including temporary occupation by the Russian Federation of the Autonomous Republic of Crimea, the city of Sevastopol and territories in Donetsk and Luhansk regions the decrease of GHG emissions in the subcategory was equal to 12.4 % in 2015 and 11.4 % in 2016 compared to 2014, certain influence on the trend had significant increase in water use tariffs also. Emissions' increasing in 2016 compared to 2015 was 1.1 %.

For details on GHG emissions at industrial wastewater treatment, see Fig. 7.15.

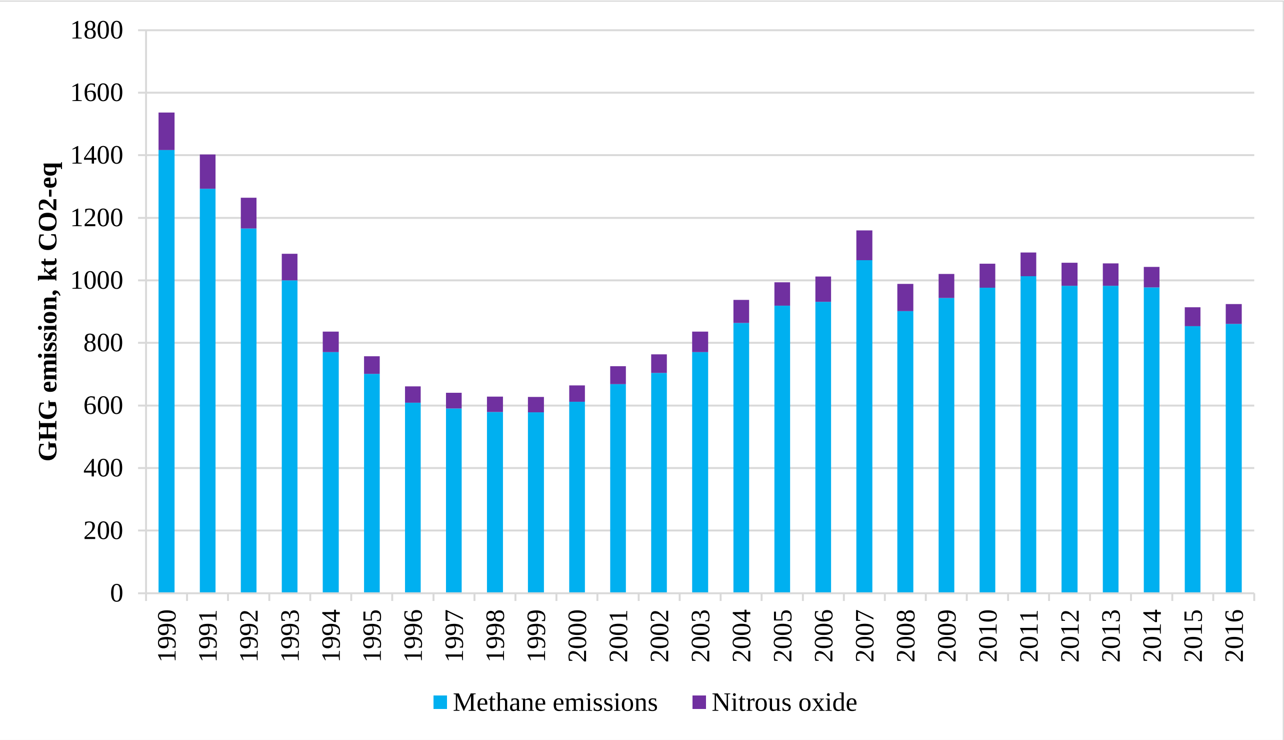


Fig. 7.15. GHG emissions from industrial sewage treatment in Ukraine, 1990-2016

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 14.55% 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 2016, 16.82 % of methane emissions were caused directly by wastewater treatment, and 83.18 % - by treatment of their sludge. Methane emissions from sewage directly, as well as from their sludge are shown in Fig. 7.16.

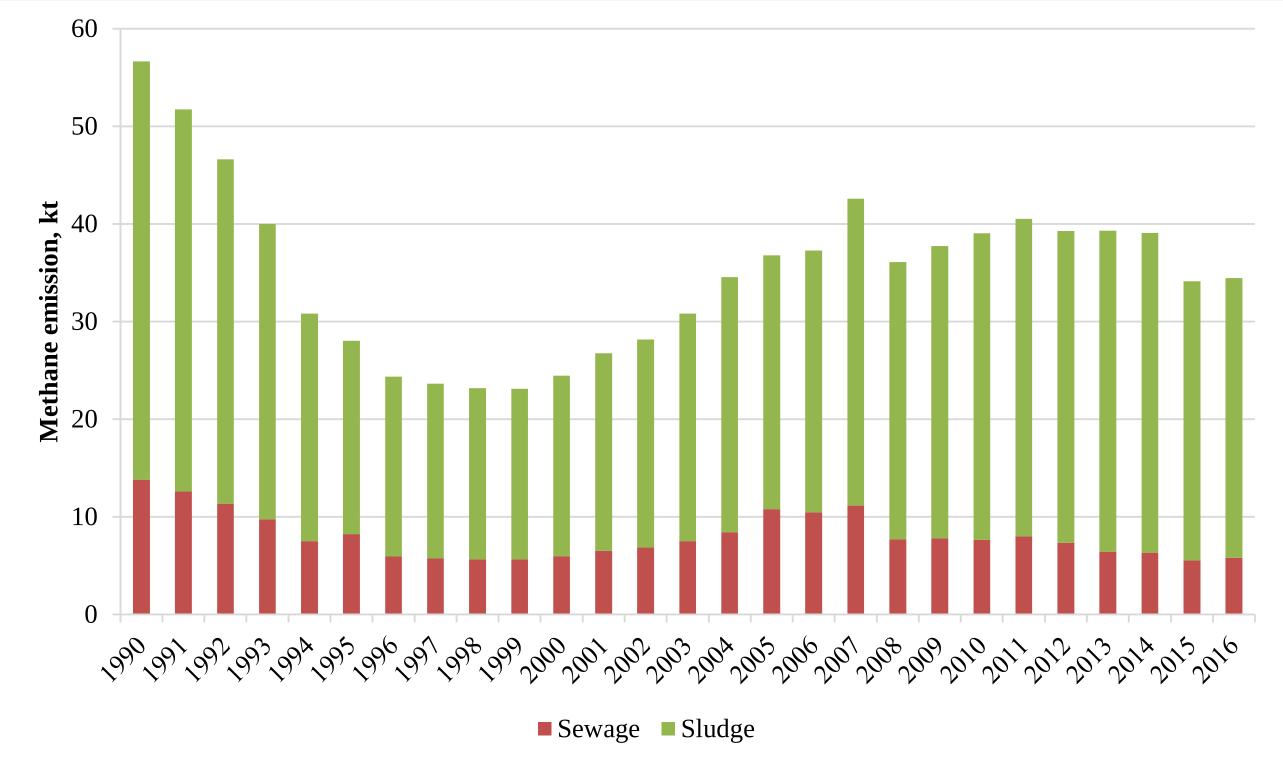


Fig. 7.16. Methane emissions from industrial sewage and sludge treatment in Ukraine, 1990-2016

GHG emissions from wastewater treatment by industry are presented in Fig. 7.17. In 2016, the largest contribution was made by food, pulp and paper, meat and dairy industries - 394.01, 159.57, and 127.91 kt CO_2-eq., respectively.

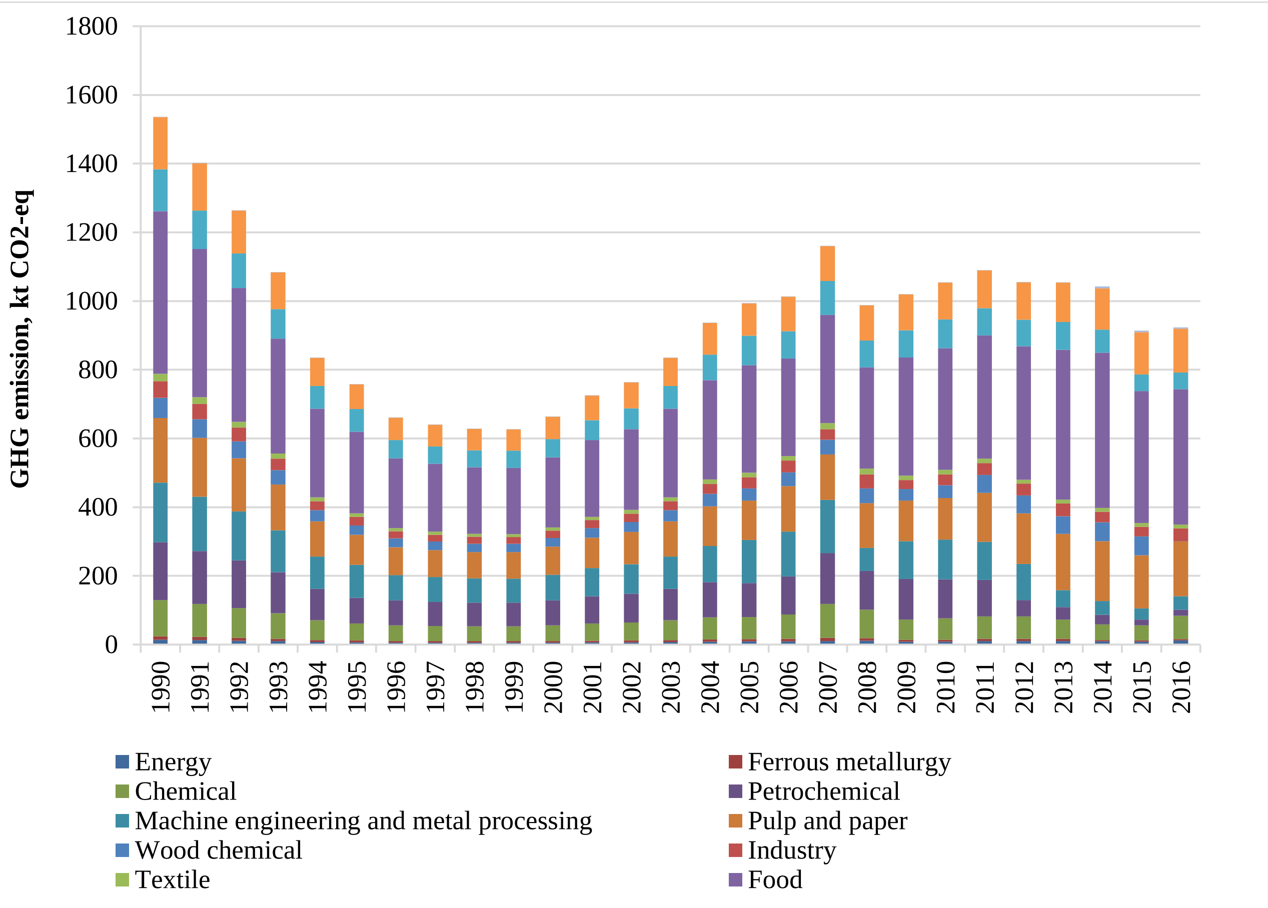


Fig. 7.17. GHG emissions from industrial sewage treatment by industries in Ukraine, 1990-2016

7.5.4.2 Methodological issues

7.5.4.2.1 General principles

Estimation of methane and nitrous oxide emissions from treatment of industrial waste water 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 [20].

Methane emissions from treatment of industrial wastewater were determined according to formula 6.5 of 2006 IPCC Guidelines [1], those of nitrous oxide - according to formula 6.7.

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.

According to data of regional state departments of ecology, no work on methane recovery at wastewater treatment is conducted in Ukraine.

7.5.4.2.2 Activity data

Generation of organic pollutants getting into industrial waste water 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 [21] taking into account the analytical study [25]. 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) resulting from production of the *i* type of products were taken based on data on the composition of wastewater. Data on consolidated standards are taken into account, since most of industrial production of Ukraine was formed back in Soviet times.

The total amount of wastewater by industries, as well as COD formation and nitrogen in them along the time series of 1990-2016 are shown in Tables 7.28-7.30.

To cover the whole territory of Ukraine, the analytical study [25] was used for 2014. In 2015 and 2016, for water consumption at temporary occupied the Autonomous Republic of Crimea and the city of Sevastopol and for temporarily occupied territories of the Donetsk and Luhansk regions it was considered trends on energy consumption in "Energy" sector.

7.5.4.2.3 Selection of emission factors

Distribution of COD flows (see Table 7.31) of industrial waste water depending on the method of their treatment 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).

Estimation of COD flows took into account aerobic decomposition of COD that are biologically treated at wastewater treatment plants - 30% [20]. COD of standard clean wastewater discharged into surface water bodies without treatment on the basis of [22] is believed to be 30 $mg/dm^{3.}$

MCF - methane emission factors (the conversion factor) - and *the COD and nitrogen removal efficiency* (see Table 7.32) for each of the methods of industrial waste water treatment were selected on the basis of the procedure [23], taking into account sanitary rules and standards of surface water protection from pollution [24].

Table 7.28. Volume of industrial wastewater by industries

Industry	Volume of sewage, million m^3										
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014***	**2015***	**2016***
Energy	423.2	202.3	182.8	265.3	260.7	305.6	296.8	308.5	284.8	254.5	352.3
Ferrous metallurgy	241.3	115.4	104.3	151.3	148.7	162.6	159.3	147.2	104.4	85.3	92.0
Chemical	205.9	98.4	88.9	129.1	122.6	157.5	149.4	125.0	102.2	85.0	62.7
Petrochemical	133.1	63.6	57.5	83.4	87.9	78.2	50.7	40.0	32.7	26.7	27.6
Machine engineering and metal processing	1153.4	551.3	498.3	723.2	733.4	723.9	671.7	352.7	312.0	266.0	346.2
Pulp and paper	485.6	232.1	209.8	304.5	334.5	346.4	368.9	396.2	431.4	372.8	399.8
Wood chemical	32.2	15.4	13.9	20.2	20.9	25.2	25.5	22.9	23.4	23.6	28.3
Industry	894.0	427.3	386.2	560.5	591.0	656.1	712.8	908.9	733.6	579.9	681.0
Textile	18.7	8.9	8.1	11.7	11.7	11.7	11.5	11.4	11.3	11.9	12.0
Food	229.8	109.9	99.3	144.1	164.1	164.8	166.0	157.6	162.2	139.6	146.3
Beverage production	116.4	55.6	50.3	73.0	77.4	70.5	70.4	73.9	65.3	49.8	48.0
Milk and meat	70.5	33.7	30.4	44.2	49.3	49.4	51.0	53.4	55.8	55.5	58.9
Fish	5.5	2.7	2.4	3.5	3.6	3.1	3.2	3.8	2.6	1.9	2.0
Total	**4009.6**	**1916.6**	**1732.2**	**2514.0**	**2605.8**	**2755.2**	**2737.3**	**2601.5**	**2321.7**	**1952.7**	**2257.1**

**Data corrected using analytical study

Table 7.29. COD generation in industrial wastewater

Industry	COD generation, thousand tons										
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Energy	22.5	10.8	9.7	14.1	13.0	18.1	17.4	19.0	18.7	17.4	28.9
Ferrous metallurgy	10.9	5.2	4.7	6.8	6.7	7.3	7.2	6.6	4.7	3.8	4.1
Chemical	83.9	40.1	36.2	52.6	49.4	52.6	51.1	43.3	35.6	32.2	57.4
Petrochemical	155.7	74.4	67.3	97.6	100.7	88.2	41.3	31.3	24.6	14.1	14.7
Machine engineering and metal processing	303.2	144.9	131.0	190.1	189.0	183.1	173.6	86.2	73.0	63.3	72.7
Pulp and paper	192.0	91.8	82.9	120.4	132.9	136.8	145.1	155.3	168.1	144.3	149.7
Wood chemical	74.9	35.8	32.3	46.9	48.7	58.9	59.6	53.3	54.6	55.0	66.1
Industry	99.2	47.4	42.9	62.2	66.4	70.1	72.0	75.1	63.8	52.3	60.7
Textile	23.2	11.1	10.0	14.5	13.7	13.1	11.5	11.7	11.6	11.7	11.6
Food	1000.2	478.1	432.1	627.1	716.9	711.9	706.7	694.8	679.8	588.3	608.0
Beverage production	115.5	55.2	49.9	72.4	79.1	70.3	69.1	70.9	61.6	48.4	46.8
Milk and meat	145.6	69.6	62.9	91.3	101.5	100.8	103.7	108.5	113.4	112.7	118.8
Fish	9.8	4.7	4.2	6.2	6.4	5.5	5.8	6.9	4.9	3.6	3.6
Total	**2236.5**	**1069.0**	**966.2**	**1402.3**	**1524.3**	**1516.8**	**1464.1**	**1363.1**	**1314.4**	**1147.2**	**1243.1**

Table 7.30. Nitrogen generation in industrial wastewater

Industry	Nitrogen generation, thousand tons										
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Energy	1.7	0.8	0.8	1.1	1.0	1.4	1.3	1.4	1.4	1.3	2.1
Ferrous metallurgy	1.7	0.8	0.7	1.1	1.0	1.1	1.1	1.0	0.7	0.6	0.6
Chemical	11.5	5.5	5.0	7.2	6.2	6.2	5.9	5.2	4.2	5.0	4.1
Petrochemical	2.8	1.4	1.2	1.8	1.8	1.6	1.0	0.7	0.5	0.5	0.5
Machine engineering and metal processing	2.3	1.1	1.0	1.4	1.5	1.4	1.3	0.7	0.6	0.5	0.7
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
Wood chemical	0.9	0.4	0.4	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8
Industry*	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
Food	14.0	6.7	6.0	8.8	9.9	10.0	9.9	10.1	9.5	8.7	8.8
Beverage production	13.5	6.4	5.8	8.4	8.9	7.8	7.7	8.4	7.1	5.0	4.7
Milk and meat	8.6	4.1	3.7	5.4	6.1	6.2	6.3	6.7	6.9	7.1	7.6
Fish	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**57.9**	**27.7**	**25.0**	**36.3**	**37.5**	**37.0**	**35.7**	**35.2**	**32.0**	**29.5**	**30.2**

* - nitrogen generation volume less than 0.1 thousand tons

Table 7.31. COD content in industrial wastewater depending on the method of its treatment, 2016

Industry	**Waste water COD, %**					**Sludge COD, %**			
	Aeration plants	Aggregators, septic tanks	Physico-chemical treatment	Mechanical treatment	Open ponds	Aeration plants	Aggregators, septic tanks	Physico-chemical treatment	Mechanical treatment
Energy	0.66	0.00	0.01	0.43	98.90	52.80	0.00	1.03	46.17
Ferrous metallurgy	1.28	0.00	0.00	17.77	80.95	5.03	0.00	0.00	94.97
Chemical	73.39	0.14	0.81	2.33	23.33	94.44	0.00	1.49	4.06
Petrochemical	75.35	0.14	9.86	0.15	14.50	84.06	0.00	15.71	0.23
Machine engineering and metal processing	4.95	0.01	2.39	30.72	61.93	9.88	0.00	6.83	83.29
Pulp and paper	78.53	0.15	0.00	3.90	17.42	93.69	0.00	0.00	6.31
Wood chemical	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Construction materials	9.38	0.02	0.00	18.69	71.90	27.00	0.00	0.00	73.00
Textile	72.69	0.17	0.00	2.45	24.69	95.63	0.00	0.00	4.37
Food	71.33	0.14	0.00	2.86	25.67	94.84	0.00	0.00	5.16
Beverage production	78.00	0.15	0.00	3.59	18.26	94.12	0.00	0.00	5.88
Milk and meat	75.70	0.15	0.00	0.70	23.44	98.76	0.00	0.00	1.24
Fish	85.88	0.16	0.00	0.00	13.96	100.00	0.00	0.00	0.00

Table 7.32. The methane conversion factor MCF and COD and nitrogen removal efficiency for each of the methods of industrial sewage treatment

The method of industrial waste water treatment		MCF	COD removal efficiency, %	Nitrogen removal efficiency, %
Aeration plants	Wastewater	0	83.9	19.6
	Sludge	0.299	-	-
Aggregators, septic tanks	Wastewater	0.050	3.0	2.7
	Sludge	0.299	-	-
Physico-chemical treatment	Wastewater	0.00	80.0	57.0
	Sludge	0.299	-	-
Mechanical treatment	Wastewater	0.00	34.0	0.0
	Sludge	0.299	-	-
Open ponds	Wastewater	0.100	-	-

Maximum capacity of methane is the default (0.25 kg $_{CH4}$ / kg COD) according to [1].

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 waste water depending on the treatment method (see Table 7.33) 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 waste water into open reservoirs was performed based on data on the degree of nitrogen removal from treatment systems according to [22]. 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 7.33. Nitrogen content in industrial wastewater, 2016, %

Industry	Treatment method				
	Aeration plants	Aggregators, irrigation fields	Physico-chemical treatment	Mechanical treatment	Open ponds
Energy	77.89	4.96	0.48	7.58	9.08
Ferrous metallurgy	86.90	5.53	6.38	0.53	0.66
Chemical	2.25	0.14	0.61	42.90	54.10
Petrochemical	0.00	0.00	0.00	0.00	0.00
Machine engineering and metal processing	0.00	0.00	0.00	0.00	0.00
Pulp and paper	6.33	0.40	0.00	38.73	54.54
Wood chemical	82.82	5.28	0.00	8.56	3.35
Construction materials	38.32	2.44	0.00	4.72	54.52
Textile	57.74	3.68	0.00	8.17	30.42
Food	76.27	4.86	0.00	2.17	16.69
Beverage production	94.01	5.99	0.00	0.00	0.00
Milk and meat	0.00	0.00	0.00	0.00	0.00
Fish	0.00	0.00	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 [20], and they are presented in Table 7.34.

Table 7.34. Uncertainty estimation ranges

Parameter	Uncertainty range, %	
	-	+
Emission factors		
B_0, kg of CH_4/kg of COD	30	30
MCF for CH_4	27.81	27.81
EF, kg of N_2O-N/kg of N	50	50
Uncertainty of CH_4 emission factors	40.91	40.91
Uncertainty of N_2O emission factors	50.00	50.00
Activity data		
Volume of waste water, m^3	8,49	8,49
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)	22.85	22.85
Uncertainty of activity data (N_2O)	22.85	22.85
Standard uncertainty of CH_4 emissions	**46.86**	
Standard uncertainty of N_2O emissions	**54.97**	

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 sub-category, no recalculations were held.

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 N_2O emissions from fuel combustion and industrial processes was calculated in accordance with 2006 IPCC guidelines [1] (Chapter 7.3, Volume 1) for all categories of the IPPU sector where NO_x emissions are allocated (2.B.1 Ammonia production, 2.B.2 Nitric acid production, 2.B.3 Adipic acid production, 2.B.8 Petrochemical and carbon black production, 2.C.1 Iron and steel production, 2.D.3.a.2 Road paving with asphalt and 2.H.1 Pulp and paper production), 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.

Table 9.1. Indirect nitrous oxide emissions

Year	Inventory Report, 2017 submission	Inventory Report, 2018 submission	Inventory Report, 2017 submission	Inventory Report, 2018 submission	Inventory Report, 2018 submission
	INDIRECT EMISSIONS (kt)		INDIRECT EMISSIONS (kt)		INDIRECT EMISSIONS (kt)
	N_2O	*N_2O*	*N_2O*	*N_2O*	*N_2O*
	ENERGY		**IPPU**		**Total**
1990	NO	11.5978	NO	0.196	11.7938
1991	NO	10.0206	NO	0.172	10.1926
1992	NO	8.8125	NO	0.152	8.9645
1993	NO	7.4503	NO	0.125	7.5753
1994	NO	6.3331	NO	0.101	6.4341
1995	NO	5.8840	NO	0.085	5.9690
1996	NO	5.4164	NO	0.096	5.5124
1997	NO	4.9320	NO	0.105	5.0370
1998	NO	4.5003	NO	0.092	4.5923
1999	NO	4.2425	NO	0.099	4.3415
2000	NO	3.9032	NO	0.107	4.0102
2001	NO	3.9421	NO	0.108	4.0501
2002	NO	3.9290	NO	0.122	4.0510
2003	NO	3.9351	NO	0.127	4.0421
2004	NO	4.1100	NO	0.118	4.2280
2005	NO	4.1493	NO	0.135	4.2843
2006	NO	4.4553	NO	0.136	4.5913
2007	NO	4.2303	NO	0.164	4.3943
2008	NO	4.2024	NO	0.151	4.3534
2009	NO	3.4936	NO	0.103	3.5966
2010	NO	3.5506	NO	0.129	3.6796
2011	NO	3.6862	NO	0.159	3.8452
2012	NO	3.5239	NO	0.158	3.6819
2013	NO	3.5189	NO	0.128	3.6469
2014	NO	3.0933	NO	0.109	3.2023
2015	NO	2.6126	NO	0.085	2.6976
2016	NO	2.6820	NO	0.095	2.7501

Indirect CO_2 emissions were not estimated.

10 RECALCULATIONS AND IMPROVEMENTS

Recalculations in current NIR were performed in all 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 2017 submission

	NIR 2017 (including LULUCF), kt CO2-eq.	NIR 2018 (including LULUCF), kt CO2-eq.	Changes, %	NIR 2017 (excluding LULUCF), kt CO2-eq.	NIR 2018 (excluding LULUCF), kt CO2-eq.	Changes, %
1990	910617.10	889282.77	-2.3	962501.52	947253.13	-1.6
1991	818994.64	798324.48	-2.5	875499.51	860921.47	-1.7
1992	760813.94	741993.13	-2.5	816810.98	803204.73	-1.7
1993	678606.60	659480.10	-2.8	725651.59	712624.43	-1.8
1994	565856.63	547814.03	-3.2	617415.00	605855.48	-1.9
1995	525395.26	508486.63	-3.2	572088.66	561325.19	-1.9
1996	482906.57	466934.91	-3.3	524370.13	514729.80	-1.8
1997	469220.19	453921.06	-3.3	507295.18	498246.11	-1.8
1998	438090.07	422617.59	-3.5	482117.12	473610.57	-1.8
1999	405217.78	390571.92	-3.6	449911.71	442352.86	-1.7
2000	389101.76	375124.77	-3.6	427645.78	420514.59	-1.7
2001	416895.19	402895.22	-3.4	450503.92	443258.40	-1.6
2002	404985.34	390529.83	-3.6	436975.09	429584.11	-1.7
2003	404640.64	391070.30	-3.4	444811.67	438017.13	-1.5
2004	414841.01	401442.94	-3.2	445778.68	438989.44	-1.5
2005	420848.14	407567.27	-3.2	450229.17	443479.88	-1.5
2006	434158.22	420903.69	-3.1	468042.15	461235.73	-1.5
2007	434386.18	421631.86	-2.9	470538.46	464193.37	-1.3
2008	436676.45	423411.99	-3.0	458294.31	451734.14	-1.4
2009	372765.49	360039.24	-3.4	397333.38	391040.66	-1.6
2010	383099.07	370178.30	-3.4	413532.30	407263.33	-1.5
2011	414205.74	400834.28	-3.2	434304.95	427801.03	-1.5
2012	398753.39	384363.06	-3.6	424214.55	417752.20	-1.5
2013	401340.84	387377.84	-3.5	415093.70	408267.75	-1.6
2014	355426.37	341952.19	-3.8	368505.88	362043.23	-1.8
2015	308640.74	296941.91	-3.8	323364.93	319011.81	-1.3

In Energy sector recalculations were performed due to following:

- Due to the error as to calculation of coal bed methane flaring in the category 1.B.1;
- Correction of errors concerning consumption of residential and non-residential natural gas in the category 1.B.2.

In IPPU sector recalculations were performed in: 2.A.2 Lime production due to adjustment of the data of lime production according to the data obtained from State Statistics Service of Ukraine [2] for 2011 - 2013 of CO_2 emissions; 2.B.1 Ammonia production recalculation of CO_2 emissions for 2015 was made due to adjustment of the data of natural gas consumption according to the data obtained from enterprises and due to adjustment of the data of NCV of natural gas obrtained from passports-certificates of physical and chemical properties of natural gas in gas production and gas transportation companies of Ukraine. 2.B.2 Nitric acid production recalculation of N_2O and NO_x emissions for 2011 - 2014 due to adjustment of the data of nitric acid production according to the data obtained from enterprises. 2.B.8 Petrochemical and carbon black production recalculation of NMVOC emissions was made in this category for the 2015 due to adjustment of the data of polystyrene production according to the data obtained from State Statistic Service of Ukraine [2]; 2.C.1 Iron and steel production recalculation of CO_2 emissions for 1990 – 2003 and 2008 in this category was due to correction of the data of limestone and dolomite consumption in steel production. Also recalculation of CO_2, CO, NO_x, NMVOC and SO_2 emissions for the 2011 - 2015 was made due to correction of the data of steel production and raw materials consumption in accordance with data obtained from enterprises-producers and in connection with clarification of data of net calorific value (NCV) of natural gas obtained from passports-certificates of physical and chemical properties of natural gas in gas production and gas transportation companies of Ukraine and carbon content in coal according to the data obtained from enterprises-producers. 2.C.2 Ferroalloys production recalculation of CO_2 emissions for the 2015 was made due to adjustment of the data of ferroalloys production according to the data obtained from enterprises; 2.F.1.(a,d) recalculation of HFC-134a, HFC-125 and HFC-143a emissions from transport refrigeration was made for the whole time series due to changes in calculation of Bank in existing equipment. Recalculation of HFC-134a, HFC-125 and HFC-143a emissions from commercial and transport refrigeration was conducted due to correction of the data on the amount of HFCs in imported equipment in accordance with data obtained from enterprises for the period of 2013 – 2015, and recalculation was performed due to allocation of the emissions from the end of the lifetime of HFCs equipment for commercial and transport refrigeration for the period of 2014 - 2015. 2.F.1.F Stationary Air Conditioning recalculation of HFC-134a emissions was conducted due to correction of the data on the amount of HFCs in imported equipment in accordance with data obtained from enterprises for 2015; 2.F.1.E Mobile Air-Conditioning recalculations was made in accordance with provisional main findings identified by the ERT of emissions from Mobile air conditioning systems in automotive vehicles for the period of 1998 – 1999 were made based on information on the import of cars in 1998 - 1999, obtained from the State Statistics Service of Ukraine[23], recalculation of HFC-134a, HFC-32 and HFC-125a emissions was conducted due to correction of the data on the amount of HFCs in exported and imported equipment for railway transport in 2015 in accordance with data obtained from enterprises. And recalculation of HFC-134a was conducted due to allocation of the emissions from the end of the lifetime of HFCs equipment for automotive vehicles 2015; 2.F.2 Foam Blowing Agents recalculation of HFC-365mfc emissions was conducted due to correction of the data on the amount of HFCs in stocks of foamed materials in 2015, in accordance with data obtained from enterprises; 2.F.3 Fire protection recalculation of HFC-227ea and HFC-125 emissions were conducted due to availability of more accurate data on the amount of HFCs in imported and used in equipment production of gas fire fighting modules (GFFMs) in 2011 – 2015, in accordance with data obtained from enterprises; 2.F.4 Aerosols recalculation of HFC-134a emissions were conducted due to availability of more accurate data on the amount of HFCs in imported and used in equipment production of aerosols in 2015, in accordance with data obtained from enterprises; 2.G.1 Electrical Equipment recalculation of SF_6 emissions was conducted in this category for 2014 - 2015 due to availability of more accurate data on the amount of SF_6 in operated gas-insulated equipment, in accordance with data obtained from enterprises.

As the improvement in 2018 submission indirect N_2O emissions for the whole time series were calculated.

During the NIR preparation recalculations in Agriculture sector have occurred in 3.A Enteric fermentation, 3.B Manure management, 3.D Agricultural soils categories and 3.H Liming (see Chapters 5.2.5, 5.3.5, 5.5.5 and 5.8.5). The are several reasons for recalculations in this categories:

- in 3.A Enteric Fermentation – reassessment of fodder consumption data, and cattle sex-age groups harmonization according to Table 10.1 2006 IPCC Guidelines [1];
- in 3.B Manure Management – recalculations, that are realized at the 3.A Enteric Fermentation category; cattle sex-age groups harmonization according to Table 10.1 2006 IPCC Guidelines [1]; swine and poultry DM values clarification; cattle, sheep, swine, poultry and other animals Nex values clarification;
- in 3.D Agricultural Soils – recalculations in category 3.B Manure Management, data of which are used in estimation of direct and indirect emissions of nitrous oxide from managed soils, and adjustment of the original data based on the SSSU's updated information;
- in 3.H Liming – using a data of inert material share in the ground lime mater.

Emissions recalculation led to its changes for entire time series (the smallest – 14.08 % in 2015, the largest – 17.08 % in 2003).

In LULUCF sector a number of recalculations was performed, particularly in following categories:

- In Settlements converted to other land uses and Land converted to Settlements – elimination of error identified in calculation sheet;
- Forest Land – minor data clarification on firest fires;
- Cropland, Grassland – revision of N input from manure due to recalculations in MMS in Agriculture and elimination of error in organic soil data in 1992.

In Waste sector recalculations were performed in subcategory 5.D.1.2 "Nitrous Oxide Emissions from Human Waste Water". Recalculation was made under estimation of indirect and direct N_2O emissions.

11 KP-LULUCF

11.1 General information

By the purpose and location, forests in Ukraine has, basically, the water protection, safety, hygiene, health, recreational, aesthetic, educational, and other functions, and are the source of meeting society's needs for forest resources [13].

Forests and forestry in Ukraine are characterized have own specifics in comparison with other European countries:

- relatively low average level of forest cover of the country's territory (15.9%);
- forest vegetation in different climatic zones (Polissya (woodlands), Forest-steppe, Steppe, Ukrainian Carpathians and Crimea Mountains), which are characterized by significant differences in the types of forest growing conditions, forest management and utilization of forest resources methods;
- high environmental importance of forests and a high share of forests (47%) with restriction for forest management
- a significant part of protected forests (15.7% of the total forest area of the State Forest Resources Agency of Ukraine, as of 01.01.2015);
- the historically formed situation with subordination of state forests to numerous permanent forest users (forests are given for permanent use to enterprises, institutions and organizations of several dozen governmental agencies and ministries);
- significant portion of forests grow in the area polluted with radiation (150 thousand hectares);
- about half of Ukraine's forests are created artificially and require intensive care.

In Ukraine, the key areas and sources to ensure balanced development of forestry were stipulated in the National Target Programme Forests of Ukraine for the period of 2010-2015 [14]. Increase of afforestation areas in this period is caused by state support to forestry enterprises. After the Programme was finished there were no policies in the field of afforestation stimulation. Thus the area of activity has declined.

As can be seen from Fig. 11.1, the State Forest Resources Agency of Ukraine, which is in charge of 73% of forests of Ukraine, is the central executive authority in the field of forestry and hunting [15].

The State Forest Resources Agency of Ukraine is the main state authority in forest and hunting management. The key tasks of the Agency are:

- implementation of state policy in forest and hunting management as well as conservation, protection, management, regeneration of forest resources and game, improving the efficiency of forest and hunting management;
- state governance in the field of forest and hunting management;
- development and organization of implementation of national, international, and regional programs in the field of protection, productivity enhancement, management, and restoration of hunting fauna, development of hunting management, and organization of forest management planning.

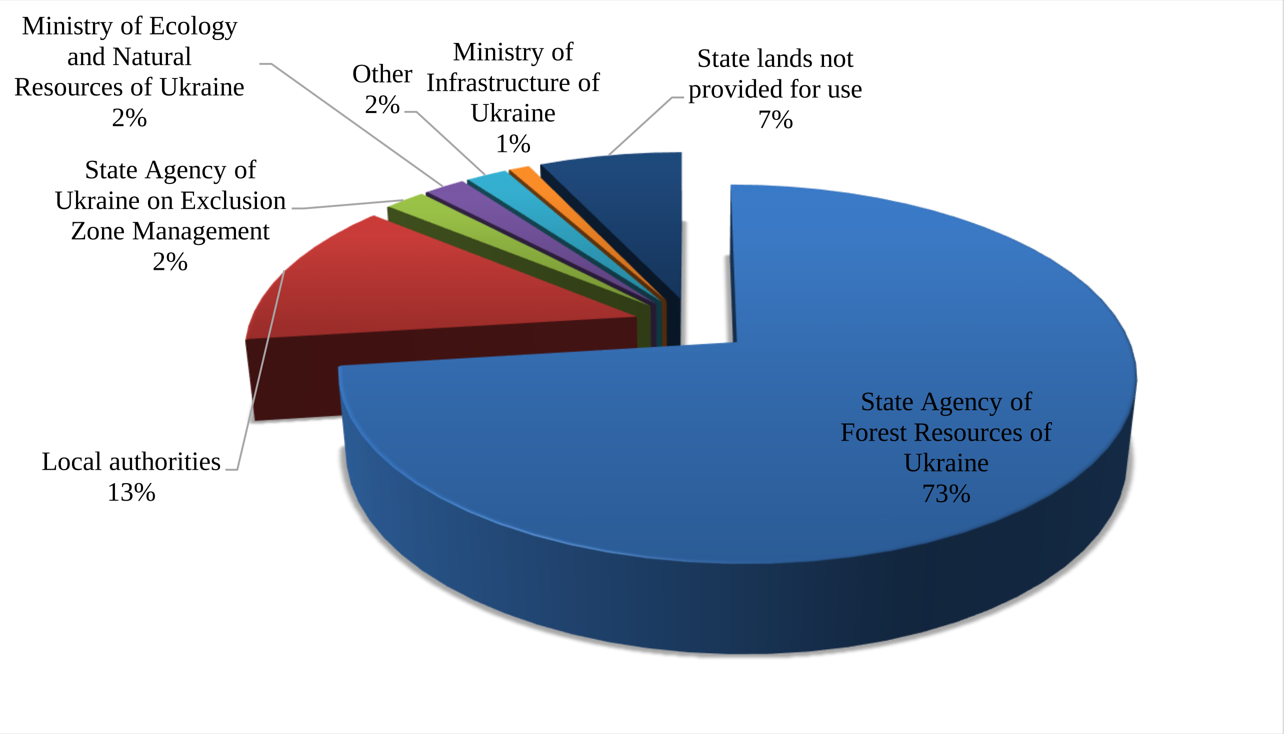


Fig. 11.1. Distribution of Ukrainian forests by permanent users.

11.1.1 Definition of the forest

As part of reporting regarding anthropogenic activities under Articles 3.3 and 3.4 KP, Ukraine accepted the following definition: "forests - forest plots with the minimal area of 0.1 hectares, minimum width of 20 meters, minimum crown coverage (or the equivalent of volume) 30% and minimum tree height at maturity - 5.0 meters". This definition is consistent with the definition of forests recommended for reporting to the Food and Agriculture Organization of the United Nations (FAO) and is used when submitting Ukraine's reports on the Global Forest Resources Assessment [3].

Ukraine agreed with the State Forest Resources Agency of Ukraine following definitions of natural and planted forests:

- "Natural forests" corresponds with Ukrainian definition of "forests of natural origin", i.e. forests regenerated naturally;
- "Planted forests" corresponds with Ukrainian definition of "forest crops", i.e. forest stands, created by planting of seedlings, saplings, sprigs of trees and shrubs or sowing its seeds (DSTU 2980-95 "Forest Crops. Definitions and Determinations").

11.1.2 Elected activities under Article 3, paragraph 4, of the the Kyoto Protocol

In the first commitment period under KP, Ukraine selected reporting on forest management as an activity under paragraph 4, Article 3 [16]. According to decision 2/CMP.7, this activity becomes mandatory for the Parties' reporting in the second commitment period. In addition to forest management, the decision of COP proposes voluntary reporting on a number of other activities under paragraph 4, Article 3. Ukraine does not intend to account for any additional activities other than forest management.

11.1.3 Description on how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

Ukraine reports under par. 3, Article 3 KP with regard to the accepted definition of *afforestation,* which is a direct result of anthropogenic activities on transformation of land that has not been forested for a period of at least 50 years, by planting, sowing and/or arising from anthropogenic activities on promotion of natural regeneration.

In the forest legislation of Ukraine, the key approaches to reforestation and afforestation are reflected in the Rules of Forest Regeneration, adopted with Resolution of the Cabinet of Ministers of Ukraine No. 303 of March 1, 2007, according to which [17]:

- Restoration of forests shall be performed by permanent forest users and forest owners on forest areas that was covered with forest vegetation (clear cuts, areas affected by fires, sparse forests, plantations that die out, and so on) by means of reforestation, and on land not previously forested, primarily unsuitable for use in agriculture or allocated for creation of protective forest plantations of the linear type - by means of afforestation.
- Land for afforestation shall be allocated in the order prescribed by the land legislation.
- The scope of work on forest regeneration and ways of its implementation shall be determined on the basis of forest inventory materials or data of special surveys, taking into account actual changes in the forest fund of Ukraine and depending on the conditions of the land subject to afforestation.
- Clear cuts, areas affected by fires shall be cleared of wood and forest residues and reforested within the period of one-two years. The forest plantations that die out shall be restored next year.

Activities of *deforestation* are a direct result of anthropogenic activities on conversion of forests to non-forest land with a change in land-use determination followed by wood harvesting, thus in the terms of national forest reporting on inventory that is shown as "conversion of forest areas into non-forest land". Changes in forest land destination are regulated by Chapter 11 of the Forest Code of Ukraine [10]. Changing the target destination of land with aim of using it for activities not related to forestry management takes place based on decisions of executive authorities or local self-government bodies (Art. 57 of the FCU). Balance sheet references on transfer and acceptance of land by forestry enterprises in the period between base forest inventory years are included in forestry organization and development project documents of these enterprises.

Since the statistical practice of Ukraine does not record transfer of land among land-use categories (see Chapter 7), to determine deforestation areas in the process of NIR preparation data from the data array on characteristics of activities, that fall under reporting in accordance with paragraphs 3 and 4, Article 3 KP were used. The array of data was collected within the framework of the research to establish and fill a database containing the characteristics of anthropogenic activities on forest land over the entire time series since 1990 [14].

Forest management is the implementation of a set of measures aimed at protection, conservation, rational use, and expanded reproduction of forests, which is reflected in Article 63 of the Forest Code of Ukraine [13]. Also, the Forest Code of Ukraine defines the basic requirements for forest management.

Some forest areas of Ukraine is excluded from the Forest Management reporting under 3.4. Particularly areas of primary beech forests and forests of Chornobyl exclusion zone, which are strictly protected by law from management activities. Thus any CSC on these areas are considered to happen as a result of natural processes and not included into C stock balance in Ukraine's submission.

Activities to create protective forest plantations and shelter belts (afforestation of unproductive, degraded, technologically contaminated land) are aimed at protecting the environment, overcoming the key destabilizing environmental factors - soil erosion and depletion of rivers.

Definitions of each activity type are consistently applied throughout the reporting period. As soon as any activity type is accounted for as an activity under Article 3.3 or 3.4 of KP, the requirement to report information on the relevant activities throughout the commitment period is complied with.

11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Since only forest management activity was chosen, the hierarchy among the different activities was not explored. Forest management is conducted only on land classified as forests.

11.2 Land-related information

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

Area larger or equal to 0.1 hectares was adopted as the unit of spatial territory assessment used for determining the area of land under the activities of paragraph 3, Article 3 of KP. This area corresponds to the minimum forest plantation area unit subject to accounting when conducting forest inventory.

11.2.2 Methodology used to develop the land-use transition matrix

Currently a new method to deliver land-use change matrix is developing. Particularly the Ministry of Ecology and Natural Resources of Ukraine and the Space Research Institute has signed Memorandum of Understanding, where both recognized needs to put efforts to deliver land-use change matrix based on satellite images. The Institute has experience in delivering land cover maps of Ukraine, using open-source data and own capacities. Limited time available during preparation of current NIR has not allowed to already use currently available data from the Institute. Thus it is planned that later this year the work will progress and the results will be available to report in NIR 2019. More details are provided in chapter 13 also.

For the current NIR previous approach of land-use change matrix development was applied, as described below.

To develop the land conversion matrix (Table 11.1), the database with plot coordinates was used for activity 3.3, and information from form F6-zem with administrative references for activity 3.4.

The algorithm for developing the database for GHG inventory in the land-use category Forest Land is presented in Annex 3.3.1. Information in the database describes the amount of activities by individual plots within forestry enterprises subordinated to the State Forest Resources Agency of Ukraine, and by administrative districts in the regions of Ukraine for forestry areas subordinated to various other economic entities in Ukraine.

Each section of the database is described individually with indication of all the necessary parameters, in line with the guidelines. Development of a designated database was carried out during the few recent years, and at this stage the work to finalize its content and design associated with processing of cartographic illustrations for the plots, for which work was performed, is under completion. The designated type of work will be performed regularly followed by updating information in the database.

The information basis for forest accounting is forest inventory materials. The forest inventory object is forest fund lands under management of enterprises, organizations, or institutions.

As a result of the described activities in Ukraine, the Plot-Wide Taxation (9.8 Mha) and mapping (7.5 Mha) databases on forest land were set up. The Plot-Wide Taxation Database of the State Forest Resources Agency of Ukraine contains information on 2.4 million plots on the area of 7.4 Mha. The Standwise Taxation Database for other forest users covers 2.4 Mha of forest land.

The work conducted made it possible to solve the problem of the balance of forest areas by the different activities of 3.3-3.4. The total value of all categories of forest land areas corresponds to final values of statistical reporting form 6-zem.

Table 11.1. Land-use transition matrix, 2016

From the previous inventory \ To the current inventory		Activities under Article 3.3: Afforestation and reforestation	Activities under Article 3.3: Deforestation	Activities under Article 3.4: Forest management	Activities under Article 3.4: Cropland management (not selected)	Activities under Article 3.4: Grazing land management (not selected)	Activities under Article 3.4: Wetland drainage and rewetting (not selected)	Other	Total area at the beginning of inventory year 2016
		kha							
Activities under Article 3.3	Afforestation and reforestation	307.52	NO						307.52
	Deforestation		50.05						50.07
Activities under Article 3.4	Forest management		0.03	9 353.91					9 353.94
	Cropland management (not selected)	NA	NA		NA	NA	NA		NA
	Grazing land management (not selected)	NA	NA		NA	NA	NA		NA
	Wetland drainage and rewetting (not selected)	NA			NA	NA	NA		NA
Other		1.44	NA	NA	NA	NA	NA	50 641.94	50 643.37
Total area at the end of inventory year 2016		322.85	50.08	9 353.91	NA	NA	NA	50 641.94	60 354.90

Note: NA - not applicable, NO - not occurred

Unlike reporting in the LULUCF sector under requirements of the UNFCCC, reporting under par. 3.3 and 3.4 of the KP is based on the requirement regarding accounting for areas by the relevant activities under par. 3 or 4, Article 3 of KP all through the commitment periods.

11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

Information is represented under Tier 1 method of the 2006 IPCC Guidelines, according to which the geographic boundary covers units of territory or lands on which numerous activities are performed.

The accumulated data set covers almost the entire territory of Ukrainian forests and meet the requirements of IPCC Tier 1 method [1]. At the same time, the Forest Inventory Database meeting Tier 2 requirements for managed forests was established for the area of 8.5 Mha, which is 89% of the total area of managed forests in the country [18].

The database "Forest Fund of Ukraine" established by the Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt" consists of three databases (sections): the database of standwise taxation characteristics of forest areas, the database of plot-wide mapping characteristics, and the database of reference information [19].

The taxation database contains descriptions of individual taxation areas, allowing use of its system of identification codes for identifying the geographic location of plots by the activities "creation of forest plantations" and "forest management". Identification of a forest land plot is ensured by use of the national unified codification system for taxation plots: administrative region code - code of the forestry enterprise - forestry compartment code - quarter - taxation plot.

Identification of afforestation or reforestation areas included into the forest management database is performed using the taxation plot codification system, and for plots not yet included into the forest stock of forestry enterprises (until registration of documents certifying the right to permanent use) - by specifying the geographic coordinates or mapping documents confirming the geographic location of the site (Fig. 11.2).

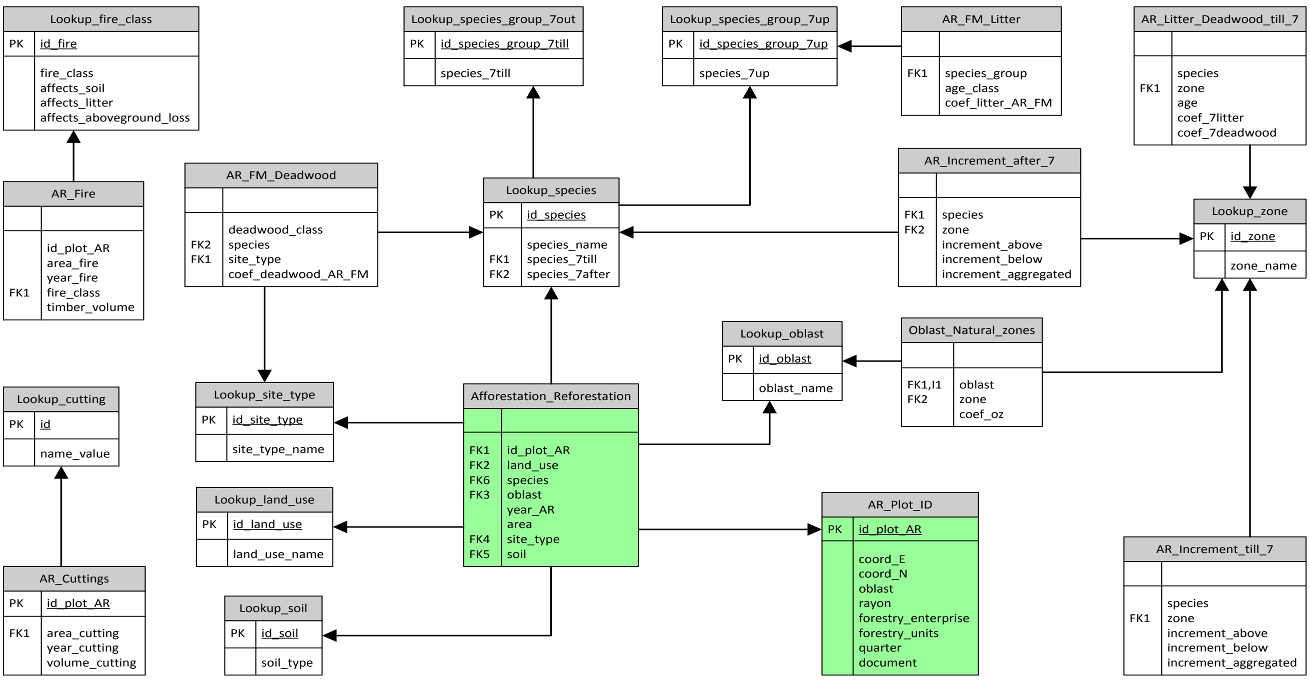


Fig. 11.2. A fragment of the afforestation and reforestation plot database schema containing a site identification table

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

To estimate changes in carbon stock in forests according to activities under par. 3 and 4, Article 3 of KP, similar methods were used as for estimation of carbon stock changes in the category Forest Land of the UNFCCC (Annex 3.3.1) [1, 12].

In order to address recommendation of ERT about forestry related data, paper archives of the Ukrderzhlisproject were scanned and currently are under digitalization process. The data includes results of forest inventories in 1988, 1996 and 2002 years. Particular attention was put to institutional distribution of forests, distribution of forest area to different land cover and land use categories, as well as age distribution by species (by area and wood stock). All the information has regional coverage (except some gap regions, for which hovewer the information will be derived as difference between summary information for Ukraine and sum of available regions).

For post-2005 period of forest inventories, digital databases are available for extracting data about forest inventories. This work is expected to be conducted in 2018. Current inventory was prepared using 2016 database on forest inventory.

Because since 1988 there were some changes in forest inventory design, the work to deliver consistent data for entire time series is to be done, and expected to be presented in 2019 submission. This is also expected to allow recalculate correction of FMRL, as recommended by the ERT.

The volume of carbon stocks on lands of activity 3.4 categories does not include volumes of carbon stocks on activity 3.3 category land to avoid double counting.

For reporting on changes in carbon stock in harvested wood products for activities 3.3 and 3.4 the approach and the input data described in section 6.8 and Annex 3.3.3 were used. HWP from Deforestation events was estimated on a basis of instant oxidation, and for Afforestation and FM by applying production approach of first-order decay methodology, provided by KP Supplement.

Forest fires in Ukraine occur as a consequence of non-intended human activity. Therefore, they are reflected in the CRF tables as "wildfires". Controlled fires (burns) do not take place in Ukraine. In the current NIR, the approach to determining GHG emissions from forest fires was revised, as described in more detail in Annex 3.3.

For afforestation and deforestation activities, GHG emissions from mineralization of nitrogen during land conversion were also estimated. For this purpose, the approach similar to the one of LULUCF was applied - Tier 1 method with default EFs. For this purpose, equations 11.2 and 11.8 of the 2006 IPCC Guidelines were used.

Ukraine does not intend to exclude GHG emissions due to natural disturbances during the second commitment period.

11.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and Forest Management under Article 3.4

When preparing reporting under Articles 3.3 and 3.4, all pools in forests were taken into consideration: above- and below-ground biomass, litter, deadwood, and soils. Regarding the pool of soils in the territory of managed forest areas, the assumption of zero carbon balance was applied. This assumption is also based on national study [4].

Currently Ukraine does not estimate GHG emissions and removals in primary forests in Carpathian region (around 59 kha), as well as areas covered by forests in Chornobyl exclusion zone (around 150 kha).

For reporting on activities under Article 3.4, no additional activities were selected by Ukraine in addition to the mandatory reporting on forest management.

Ukraine does not submit reporting on CO_2 and N_2O emissions as a result of liming and fertilizer application in forestry due to the fact that this activity is not held in forest areas, and fertilization takes place in negligibly small quantities.

1.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

Estimation of emissions from sources and removals by sinks as a consequence of elevated carbon dioxide concentrations above pre-industrial levels and indirect nitrogen deposition, as well as of dynamic effects of the age structure change resulting from activities prior to January 1, 1990 were not held due to lack of an estimation technique.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

There were no recalculations in current NIR.

11.3.1.5 Uncertainty estimates

The primary factors that impact the uncertainty in this category are:

- accuracy of determining the area of forest land on which afforestation processes take place, and their distribution by categories;
- accuracy of biomass growth estimation;
- accuracy of conversion coefficients.

For the area uncertainty is around 10% [4], for the data on biomass growth rate - approximately 25%, on the ratio of above-ground and below-ground biomass - 15% [1, 4]. Uncertainties related to estimation of the carbon content in biomass are 2% [1]. Since the data was obtained from different sources, it is assumed that it is not correlated. The value of the combined uncertainty of carbon removals in the territories where there are afforestation and/or reforestation processes taking place is 5%, with consideration of the uncertainty level of carbon accumulation in litter and soils - 10%.

11.4 Article 3.3

11.4.1 Information that demonstrates that the activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are directly human-induced

Control over implementation of forest management projects to improve effectiveness of their implementation, operational elimination of discovered deficiencies in forest management and forest management planning in Ukraine is performed in accordance with the Forest Code of Ukraine, as well as other regulatory instruments [13, 21, 45].

The following documents and materials are used during the control procedure:

- materials of the forest management plan (explanatory note, taxation descriptions, design sheets, forest inventory tabs);
- annual reports of the forestry enterprise on its economic and industrial activity in the period from the start of the management plan, including the year prior to the control one;
- duly issued acceptance or transfer acts on forest fund land from the forestry company, as well as decisions of competent authorities in these matters;
- in case of transfer of forest land for long-term use (rent) - the decision of competent authorities and the contract stating rights and obligations of the parties;

- cutting area allocation materials and acts of logging site control;
- forest inventory logs (accounting of the forest fund);
- log to register forest plantations, forest fires, forest violations, loss of forests, etc.;
- materials of inventory of forest crops and protective forest plantations, orchards, areas where activities are implemented to promote natural regeneration of forests;
- acts of technical acceptance of forest crops and their transfer into land covered with forest vegetation;
- other acts of full-scale surveys of the forest areas where changes occurred as a result of fires, windbreaks, etc.

Activities under Article 3.3 started after January 1, 1990. This is confirmed with response letters from forestry companies obtained as a result of a questionnaire research conducted at the time of setting up the information array for the database. Based on findings of this survey, documented evidence of the start of activities under Article 3.3 of KP were obtained.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Forest logging activity in Ukraine is regulated with a certain set of legal documents, including Rules of Final Felling and Rules of Improving the Qualitative Composition of Forests.

In accordance with these documents and depending on the method of wood removal, three logging systems are distinguished – clear cuttings, gradual, and selective [21]. Regardless of the selected method of logging, Rules of Forest Restoration oblige the forest user to reforest the area where logging was performed. Reforestation can be held naturally (natural reforestation and support for natural recovery), as well as artificially - by planting entirely or partially forest crops. The Rules of Forest Restoration stipulate compulsory reforestation of all the areas that lost their forest cover as a result of logging and fires during one to two years.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforestation

Since deforestation implies further change of the land-use category of forest land, the process of conversion into another land category, in accordance with Article 57 of the Forest Code of Ukraine, primarily is carried out by executive authorities or local self-government bodies in coordination with executive bodies on forestry and environmental protection. In view of the above mentioned, in Ukraine there are no forest areas that lost their forest cover but are still not classified as deforested.

11.5 Article 3.4

11.5.1 Information that demonstrates that the activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

Forest management activities after January 1, 1990 were selected for reporting under Article 3.4 of KP during the first commitment period. According to decision 2/CMP.7, during the second period this type of activity is required for the countries listed in the third column in KP Annex B. No additional activities for reporting on par. 4, Article 3 of KP were selected by Ukraine.

Almost all forests of Ukraine are impacted by economic activities, as justified by statistical data of the state forest inventory, taxation databases, national statistical information on activities in the forestry sector. Areas of forests classified as primary forests (59 kha) were not taken for estimation. These areas are consistent with the values declared to FAO. Also forests in Chornobyl exclusion zone (150 kha) are not included into estimation of GHG emissions and removals.

11.5.2 Information relating to Cropland Management, Grazing Land Management, Revegetation and Wetland Drainage and Rewetting if elected, for the base year

Ukraine did not select these activities.

11.5.3 Information relating to Forest Management

Ukraine adopted a "broad" definition of forest management in accordance with the Annex to decision 11/CP.7, as a system of practices for conservation and management of forests aimed at fulfilling relevant ecological (including biological diversity), economic, and social functions of forests on the sustainable basis.

In the context of this definition, the types of activities carried out in forest-covered areas of forest land in Ukraine, according to information published annually by the State Statistics Service of Ukraine (Form 3-lg):

- controlled cuttings in accordance with forestry management plans (see Chapter 11.4.2.);
- forests protection from pests and diseases (with biological and chemical products, elimination of breeding site of pests and diseases with the help of implementation of special events);
- conducting fire prevention measures.

Management prescriptions for forest management are provided in the Forest Code of Ukraine [13], Rules of Forest Regeneration [17], Rules of Final Harvest[21], Rules of Final Harvest in Mountain Forests of Carpathians [45].

11.5.4 Conversion of natural forest to planted forest

Forestry in Ukraine is oriented in promotion of natural regeneration of forests. Particularly after harvesting of natural forests high priority is given to natural regeneration of cutting areas.

11.5.5 Technical adjustments proposed by Ukraine pursuant to paragraph 14 of the Annex to decision 2/CMP.7

Paragraph 14 of the Annex to decision 2/CMP.7 requires that the Parties complied with methodological consistency between the reference level determined by countries in response to decision 2/CMP.6, and information provided on forest management in the second commitment period.

In NIR 2016 Ukraine provided information on revision of FMRL. The ERT recommended to use age-dependent EFs, and derive data necessary to use these factors. Since 2016 year there is a significant challenge in institutional capacity of Ukraine to collect data regarding forests of Ukraine. Particularly this is connected with financial shortage of the Ukrainian State Project Forest Inventory Production Association "Ukrderzhlisproekt", which is maintaining databases of activities and properties of forests.

In order to fulfil requirements of reporting under KP-LULUCF, as well as address recommendation of ERT, one expert from the Ministry of Ecology and Natural Resources of Ukraine and one from National Center for GHG Emission Inventory were appointed and agreed by Ukrderzhlisproekt to derive data from paper sources.

Since 2005 electronic databases are available to select and download data for necessary calculations. To be able to use it special training was performed by experts of Ukrderzhlisproekt. Practice was performed on 2016 database, and control checks were done to ensure correctness of downloaded data. That data was used for current NIR.

Further work includes scanned copies digitalization, downloading of data for 2005-2015 with necessary structure, combining data from these sources, ensuring time series consistency. It is expected to finish the work, perform necessary recalculations in LULUCF and KP-LULUCF sectors, and report the results in 2019 submission.

12 INFORMATION ON ACCOUNTING OF KYOTO UNITS

12.1 Background information

Annex I Parties are required to report their national registries' holdings and transactions of Kyoto units and inform about related issues as specified in Decision 15/CMP.1 Section E. The following chapters serve this purpose.

12.2 Summary of information reported in the SEF tables

Information from the national registry on acquisition, holding, transfer, cancellation, retirement and carry-over of AAUs, RMUs, ERUs, CERs, tCERs and lCERs for 2017 has been reported as separate files ('RREG1_UA_2017_1_1', and 'RREG1_UA_2017_2_1') in xls and xml format each by separate upload.

The SEF for CP2 2016 was generated on 6 September 2017 by the SEF application version 3.7.4, provided by the secretariat at 15.02.2017. The SEF for CP1 2016 was generated on 21 July 2017 by the SEF application version 3.7.4, provided by the secretariat at 15.02.2017.

Further details can be found in the electronic SEF files as mentioned above and published at the UNFCCC website:
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/10116.php

12.3 Discrepancies and notifications

No discrepancies occurred in 2017. Therefore, no report R-2 is submitted.

No CDM notifications occurred in 2017. Therefore, no report R-3 is submitted.

No non-replacements occurred in 2017. Therefore, no report R-4 is submitted.

No invalid units exist at the 31 December 2017. Therefore, no report R-5 is submitted.

There were no actions necessary to correct any problem causing a discrepancy because there were no discrepancies in 2017.

12.4 Publicly accessible information

Section E of the annex to Decision 15/CMP.1 outlines provisions for making available non-confidential information to the public via a user interface. Ukraine makes available publicly accessible information on the official website of the Registry: http://www.carbonunitsregistry.gov.ua. The website also publishes reports on holdings and transactions in the Registry.

12.5 Calculation of the commitment period reserve (CPR)

The estimated value of the CPR of Ukraine is calculated as 100% of the amount of GHG emissions in its latest inventory submissions multiplied by eight. The latest inventory submission is Ukraine's Greenhouse Gas Inventory 1990-2015.

According to this inventory, the estimated value of the CPR is as follows:

$$338,636,090 \times 8 = 2,709,568,720 \text{ t } CO_2 \text{ eq.}$$

Thus, **the estimated value of the Ukraine's CPR** is **2,709,568,720** tonnes of carbon dioxide equivalent.

12.6 KP-LULUCF accounting

For the second KP commitment period, Ukraine intends to report at the end of the period.

Information on emissions and removals by the activities under paragraphs 3 and 4, Article 3 of KP is presented in Table 12.1. More details are provided in the CRF "Accounting" table for KP-LULUCF.

Table 12.1. Results of activities under Articles 3.3 and 3.4 of KP

Greenhouse gas source and sink activities	Net emissions/removals					Accounting Parameters	Accounting Quantity
	2013	2014	2015	2016	Total		
	kt CO_2-eq.						
A. Article 3.3 activities							
A.1. Afforestation/reforestation	-929.73	-972.76	-1079.44	-1251.29	-4233.22		-2967.80
Excluded emissions from natural disturbances	NA	NA	NA	NA	NA		NA
Excluded subsequent removals from land subject to natural disturbances	NA	NA	NA	NA	NA		NA
A.2. Deforestation	12.02	8.54	8.41	9.10	38.07		28.98
B. Article 3.4 activities							
B.1. Forest management					-275225.85		-21259.87
Net emissions/removals	-69087.86	-69614.42	-68962.59	-67560.98	-275225.85		
Excluded emissions from natural disturbances	NA	NA	NA	NA	NA		NA
Excluded subsequent removals from land subject to natural disturbances	NA	NA	NA	NA	NA		NA
Any debits from newly established forest (CEF-ne)	NA	NA	NA	NA	NA		NA
Forest management reference level (FMRL)						-48700.00	
Technical corrections to FMRL						-13435.00	
Forest management cap						262671.18	-21259.87
B.2. Cropland management (if elected)	NA	NA	NA	NA	NA		NA
B.3. Grazing land management (if elected)	NA	NA	NA	NA	NA		NA
B.4. Revegetation (if elected)	NA	NA	NA	NA	NA		NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA	NA		NA

13 INFORMATION ON CHANGES IN THE NATIONAL GHG INVENTORY SYSTEM

According the content and recommendations from main findings of review of the inventory submission of Ukraine submitted in 2015 (ARR 15) Part started significant improvement of spatial component of the national inventory system in following directions directions: (a) Organizational and structural improvement, (b) expanding the list of sources of information, (c) use of modern methods and methodologies of data processing , (d) experimental steps aimed to verification of transition to new technologies

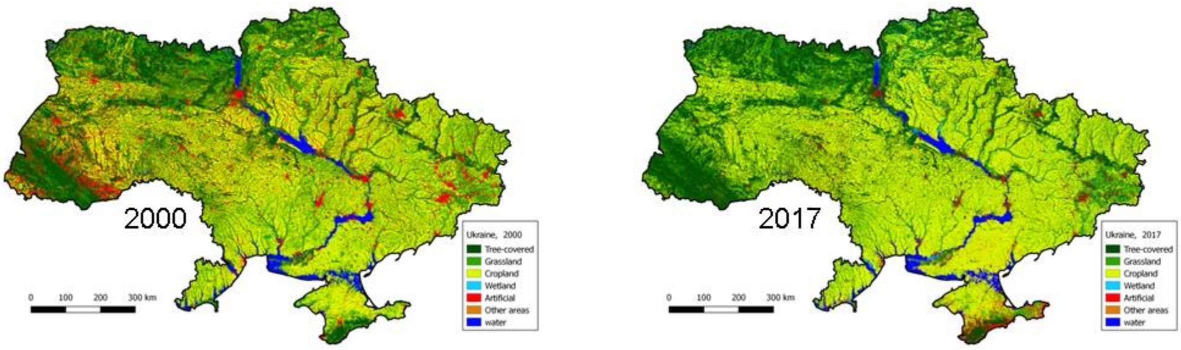
The first step of this activity was the memorandum of cooperation between Ministry of Ecology and Natural Resources of Ukraine and Space Research Institute NAS Ukraine and SSA Ukraine (https://menr.gov.ua/news/32169.html) signed on the 7th of March 2018.

The territory of Ukraine is large in area, and therefore satellite data processing for creation land cover maps for the whole territory of the country requires the development and exploitation of automated methods based on artificial intelligence and machine learning over the time series of satellite data. Taking into account the large amount of satellite data that should to be processed for land cover creation, solving this problem requires the use of high-performance cloud computing with fast data access.

SRI NASU-SSAU is a leading scientific institution in the field of development and exploitation of machine learning technologies for geospatial information processing. The methods developed by the experts of the Institute and the cloud-based classification technologies based on deep learing technicues provide a possibility to assess the indicators and to monitor the achievement of the goals of sustainable development over the territory of whole country.

Ukraine is a party of international programs, conventions and initiatives (including ones on the UN level) for environmental monitoring, in particular the United Nations Framework Convention on Climate Change, the Kyoto Protocol, the UN Convention to Combat Desertification, etc. As part of this activity, international institutions require from the Ministry of Ecology and Natural Resources of Ukraine to create land cover maps for the whole country on a regular basis and assess existing changes in land use.

Content of document	Name of file	URL
Scanned original memorandum (Ukrainian language)	Memorandum_MENR_IKD_07_03_2018.pdf	https://menr.gov.ua/files/images/news/16032018/memorandum_MENR_IKD_07_03_2018.pdf
The text of the memorandum in Word format (Ukrainian language)	Memorandum_MENR_IKD_07_03_2018.docx	https://menr.gov.ua/files/images/news/16032018/memorandum_MENR_IKD_07_03_2018.docx
Unofficial translation of the text of the memorandum in pdf format	Memorandum_MENR_IKD_07_03_2018_engl_tansl.pdf	https://menr.gov.ua/files/images/news/16032018/Memorandum_MENR_IKD_07_03_2018_engl_tansl.pdf
Unofficial English translation of the text of the memorandum	Memorandum_MENR_IKD_07_03_2018_engl_tansl.docx	https://menr.gov.ua/files/images/news/16032018/Memorandum_MENR_IKD_07_03_2018_engl_tansl.docx



Land cover maps for the territory of Ukraine 2000-2017 developed by experts of SRI NASU-SSAU

14 INFORMATION ON CHANGES IN THE NATIONAL REGISTRY

14.1 Information on changes according to Decision 15/CMP.1

The following table summarises the changes to the National Registry of Ukraine in 2017.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	A change of the name of the registry administrator and the alternate registry administrator occurred and reported to the UNFCCC in March 2017.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	No change was applied to the database structure. The database model, is provided in Annex A (separate upload). Ukraine provided a disaster recovery plan to the ERT (as confidential information) and formally submitted the plan on 7 September 2017, together with the addendum to chapter 14 of the NIR of the 2017 annual submission. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	No change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No change regarding security occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Since 3 August 2015 including beginning of the year 2016 the Registry was disconnected from ITL. Since 3 August 2016 it was reconnected to ITL in no operations mode. Since 23 August 2016 the Registry was switched to a "reconciliation only" mode. Full functionality of the Registry was restored on 23 June 2017. In November 2017 Ukraine proposed preliminary project time frame for upgrade of the national registry having CP2 functionality with the ITL and completion of the annex H, which were expected for the end of February 2018. On 27 February 2018, Ukraine informed the ERT that the planned establishment of the connection faced some technical issues causing delays in ambitious preliminary plan. At this point of time the deployment of the CP2 national registry and production platform were to be implemented and it was an on-going work on options to ensure correct and secure process of data migration between the CP1 and the CP2 Ukrainian national registries. On 16 April 2018, Ukraine successfully established a connection from its upgraded national registry to the ITL and on 17 April started the annex H test, which successfully concluded on 24 April 2018. The ERT received the Annex H test results for the national registry of Ukraine on 2 May 2018 and a confirmation from the ITL that the national registry of Ukraine is connected to the ITL on 14 May 2018.

14.2 Previous Annual Review recommendations

Ukraine was a subject to an individual inventory review in 2017. The review of the 2017 annual submission of Ukraine organized by the secretariat, in accordance with the Article 8 review guidelines (decision 22/CMP.1, as revised by decision 4/CMP.11).

FCCC/ARR/2014/UKR includes recommendation related to the registry those have been successfully resolved:

Status of implementation of issues and/or problems raised in the previous review report of Ukraine

ID#	*Issue and/or problem classification*[a]	*Recommendation made in previous review report*	*ERT assessment and rationale*
General			
G.1	National registry – (G.3, 2016) Adherence to reporting guidelines under Article 7, paragraph 1, of the Kyoto Protocol	Ensure the proper functioning of the national registry and meet the requirements specified in section II of the annex to decision 13/CMP.1 and the detailed technical requirements for national registries defined in the data exchange standards.	Resolved. During the review in September 2017, the ERT concluded that the national registry of Ukraine was not meeting the mandatory requirements for the registry's functionality for CP2. In that context, the ERT noted that the national registry of Ukraine does not fully comply with the functions set out in section II of the annex to decision 13/CMP. 1 in conjunction with decision 3/CMP.11. In addition, the ERT also noted that it does not fully comply with decision 1/CMP.8, in particular paragraphs 21, 23, 24 and 26 of decision 1/CMP.8 and paragraphs 16, 21, 33, 34 and 36 of annex to decision 13/CMP.1 in conjunction with decision 3/CMP.11. The ERT included this issue in the list of potential problems and further questions raised by the ERT. The ERT recommended that Ukraine ensure the proper functioning of the national registry, in particular by implementing the additional functionality for the CP2 that was introduced by decision 3/CMP.11, and also that functionality that was introduced by decision 1/CMP.8. The ERT considered that the proper functioning of the national registry could be achieved by developing and implementing a software functionality that includes the CP2 functionality so that the national registry of Ukraine fully meets the requirements specified in section II of the annex to decision 13/CMP.1 in conjunction with decision 3/CMP.11, other relevant decisions by the CMP, such decision 1/CMP.8, and the data exchange standards for registry systems under the Kyoto Protocol. Ukraine, in accordance with paragraph 6 of decision 1/CMP.8, implements its responsibilities in relation to the CP2 in a manner consistent with its mandatory national legislation, including budget and public procurement legislation that does not allow to conduct public procurement with the purpose to implement provisions of international agreements that do not have legal force yet at national level. Ukraine further indicated that it is currently performing the activities aimed to ensure the proper functioning of the national registry for the CP2 on a voluntary basis. Consequently, on 16 April 2018, Ukraine successfully established a connection from its CP2 national registry to the ITL and on 17 April started the annex H test, which successfully concluded on 24 April 2018. The ERT received the Annex H test results for the national registry of Ukraine on 2 May 2018 and a confirmation from the ITL that the national registry of Ukraine is connected to the ITL on 14 May 2018. Therefore, the ERT considers that

ID#	Issue and/or problem classification[a]	Recommendation made in previous review report	ERT assessment and rationale
			the national registry of Ukraine meets the mandatory requirements for national registry's functionality for CP2 introduced by decisions 1/CMP8 and 3/CMP.11 and meets the requirements specified in section II of the annex to decision 13/CMP.1 in conjunction with 3/CMP.11 and decision 1/CMP.8, and the data exchange standards for registry systems under the Kyoto Protocol. The ERT also considers that the potential problem has been satisfactorily resolved.
G.2	National registry – (G.4, 2016) Adherence to reporting guidelines under Article 7, paragraph 1, of the Kyoto Protocol	Update the information on the national registry website (carbonunitsregistry.gov.ua) and ensure that the publicly available information is up to date (i.e. updated as close to real time as possible, but updated on a monthly basis at a minimum).	Resolved. All information on the national registry website was updated on 7 September 2017, including the publicly available information. Ukraine also intends to update further all information as close to real time as possible.
G.3	National registry – (G.4, 2016) Adherence to reporting guidelines under Article 7, paragraph 1, of the Kyoto Protocol	Include up-to-date account information, project information under Article 6 of the Kyoto Protocol, holding and transaction information, and a list of legal entities authorized by the Party.	Resolved. Information on projects under Article 6 of the Kyoto Protocol, holding and transaction information, and a list of legal entities authorized by the Party were updated on the website of the national registry, and information on accounts was enhanced and is now compliant with requirements in the annex to decision 13/CMP.1, paragraph 45, in conjunction with decision 3/CMP.11.
G.4	Kyoto Protocol units – (G.5, 2016) Adherence to reporting guidelines under Article 7, paragraph 1, of the Kyoto Protocol	Report information on Kyoto Protocol units in accordance with decision 15/CMP.1 and decision 3/CMP.11.	Resolved. The SEF tables for CP2 for the years 2013, 2014, 2015 and 2016 were formally submitted by Ukraine on 6 September 2017 during the review week. An addendum to chapters 12 and 14 of the NIR of the 2017 annual submission of Ukraine with additional information on its accounting of Kyoto Protocol units was submitted on 7 September 2017.
G.5	Kyoto Protocol units – (G.6, 2016) Adherence to reporting guidelines under Article 7, paragraph 1, of the Kyoto Protocol	Prepare and submit a disaster recovery plan and the other information collected annually on the registry transactions and security.	Resolved. During the review, Ukraine provided a disaster recovery plan to the ERT (as confidential information) and formally submitted the plan on 7 September 2017, together with the addendum to chapter 14 of the NIR of the 2017 annual submission.

15 MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

Ukraine, being a party not included in Annex 2 to the UNFCCC and being an economy in transition, has no relevant financial commitments under paragraphs 3-5, Article 4 of the Convention. However, realizing the need to stabilize and improve the ecological condition of the Earth, ensure sustainable development and assist developing countries, Ukraine makes its contribution to strengthening the capacities of developing countries in the field of climate change prevention by training the qualified specialists.

Information about number of foreign citizens from developing countries, who studied in the specialty "Ecology" in the higher education institutions of Ukraine in 2016, is presented in the table below and based upon the statistics received from the Ministry of Education and Science of Ukraine (letter № 7.3-15-367-18 dated April 11, 2018).

#	Name of Ukrainian Educational Institution	Country	Amount of Students
1	National University of Life and Environmental Sciences of Ukraine	Azerbaijan	1
2	National University of Life and Environmental Sciences of Ukraine	Algeria	1
3	National University of Life and Environmental Sciences of Ukraine	Cameroon	1
4	National University of Life and Environmental Sciences of Ukraine	Uzbekistan	1
5	Mariupol State University	Azerbaijan	4
6	V.N. Karazin Kharkiv National University	Jordan	1
7	Zaporizhzhya National University	Ecuador	1
8	Natonal Technical University "Kharkiv Politechnic Institute"	Azerbaijan	1
9	Natonal Technical University "Kharkiv Politechnic Institute"	Congo	1
10	National University of Shipbuilding named after Admiral Makarov	Turkmenistan	1
11	Kharkiv National University of Construction and Architecture	Turkmenistan	1
12	Kyiv National University of Construction and Architecture	Algeria	1
13	Kyiv National University of Construction and Architecture	Angola	1
14	National Metallurgical Academy of Ukraine	Angola	5
15	National Metallurgical Academy of Ukraine	Congo	1
16	National Metallurgical Academy of Ukraine	Libya	1
17	Tavriya State Agrotechnological University	Guinea	1
18	Sumy National Agrarian University	Turkmenistan	1
19	National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"	Azerbaijan	1
20	Odessa State Ecological University	Azerbaijan	4
21	Odessa State Ecological University	Moldova	2
22	Odessa State Ecological University	Turkmenistan	1
23	Odessa National Polytechnic University	Libya	1

#	Name of Ukrainian Educational Institution	Country	Amount of Students
24	Odessa National Polytechnic University	Nigeria	1
25	Odessa National Polytechnic University	Turkmenistan	1
26	Private Higher Educational Institution University "European University"	Georgia	3
27	Uman National University of Horticulture	Turkmenistan	1
28	Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan	Nigeria	1
30	Kharkiv National University of Municipal Economy named after O.M. Beketov	Iraq	1
In Total			43

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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 1990 (Tables A1.2 – A1.3), and analysis of emission trends for 2016 (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 in 1990, kt CO_2-eq.	Share in total emissions in 1990	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	121 545.98	0.128	0.13
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	96 756.68	0.102	0.23
2.C.1 Iron and Steel Production	CO_2	79 689.69	0.084	0.31
1.B.1 Fugitive emissions from Solid Fuels	CH_4	61 923.39	0.065	0.38
1.A.3.b Road Transportation	CO_2	59 916.59	0.063	0.44
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	58 071.11	0.061	0.50
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	0.66

IPCC source category	Gas	Emissions in 1990, kt CO_2-eq.	Share in total emissions in 1990	Cumulative total of Column D
A	B	C	D	E
3.A Enteric Fermentation	CH_4	45 924.87	0.049	0.71
1.A.3.e Other Transportation	CO_2	39 807.94	0.042	0.75
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	33 008.26	0.035	0.79
3.D.1 Direct N2O Emissions From Managed Soils	N_2O	30 549.23	0.032	0.82
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	29 955.80	0.032	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	9 402.92	0.010	0.91
2.A.1 Cement Production	CO_2	9 400.94	0.010	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	0.006	0.94
3.D.2 Indirect N2O Emissions From Managed Soils	N_2O	5 160.72	0.005	0.94
2.A.2 Lime Production	CO_2	5 121.81	0.005	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 A1.3 Key categories analysis by level, including LULUCF, in 1990

IPCC source category	Gas	Emissions in 1990, kt CO_2-eq.	Share in total emissions in 1990	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	121 545.98	0.118	0.12
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	96 756.68	0.094	0.21
2.C.1 Iron and Steel Production	CO_2	79 689.69	0.077	0.29
4.A.1 Forest Land Remaining Forest Land	CO_2	-63 405.76	0.061	0.35
1.B.1 Fugitive emissions from Solid Fuels	CH_4	61 923.39	0.060	0.41
1.A.3.b Road Transportation	CO_2	59 916.59	0.058	0.47
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	58 071.11	0.056	0.52
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	53 148.53	0.051	0.58
1.A.4 Other Sectors - Solid Fuels	CO_2	48 177.92	0.047	0.62
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	48 058.63	0.047	0.67
3.A Enteric Fermentation	CH_4	45 924.87	0.044	0.71
1.A.3.e Other Transportation	CO_2	39 807.94	0.039	0.75
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	33 008.26	0.032	0.78
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	30 549.23	0.030	0.81
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	29 955.80	0.029	0.84
1.A.4 Other Sectors - Gaseous Fuels	CO_2	26 458.72	0.026	0.87
1.A.4 Other Sectors - Liquid Fuels	CO_2	23 334.88	0.023	0.89
4.D.1.1 Peat Extraction Remaining Peat Extraction	CO_2	11 971.34	0.012	0.90
2.B.1 Ammonia Production	CO_2	9 402.92	0.009	0.91
2.A.1 Cement Production	CO_2	9 400.94	0.009	0.92
5.A Solid Waste Disposal	CH_4	6 534.85	0.006	0.93
2.B.2 Nitric Acid Production	N_2O	5 284.58	0.005	0.93
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	5 160.72	0.005	0.94

IPCC source category	Gas	Emissions in 1990, kt CO_2-eq.	Share in total emissions in 1990	Cumulative total of Column D
A	B	C	D	E
2.A.2 Lime Production	CO_2	5 121.81	0.005	0.94
4.B.1 Cropland Remaining Cropland	CO_2	-4 643.74	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
3.B Manure Management	CH_4	3 747.21	0.004	0.95
Other				1,00

Table A1.4. Key categories analysis by level, excluding LULUCF, in 2016

IPCC source category	Gas	Emissions in 2016, kt CO_2-eq.	Share in total emissions in 2016	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	70 620.66	0.209	0.21
2.C.1 Iron and Steel Production	CO_2	42 989.72	0.127	0.34
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	25 667.40	0.076	0.41
1.A.4 Other Sectors - Gaseous Fuels	CO_2	25 337.78	0.075	0.49
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	24 878.27	0.073	0.56
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	24 464.97	0.072	0.63
1.A.3.b Road Transportation	CO_2	22 694.40	0.067	0.70
1.B.1 Fugitive emissions from Solid Fuels	CH_4	16 347.07	0.048	0.75
3.A Enteric Fermentation	CH_4	10 752.01	0.032	0.78
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10 113.86	0.030	0.81
5.A Solid Waste Disposal	CH_4	8 231.30	0.024	0.83
1.A.3.e Other Transportation	CO_2	7 670.29	0.023	0.86
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	7 320.84	0.022	0.88
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	3 997.98	0.012	0.89
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	3 802.46	0.011	0.90
2.A.1 Cement Production	CO_2	3 622.85	0.011	0.91
5.D Wastewater Treatment and Discharge	CH_4	2 985.18	0.009	0.92
2.B.1 Ammonia Production	CO_2	2 662.89	0.008	0.93
2.A.2 Lime Production	CO_2	2 472.21	0.007	0.94
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	1 907.61	0.006	0.94
2.B.2 Nitric Acid Production	N_2O	1 877.17	0.006	0.95
2.C.2 Ferroalloys Production	CO_2	1 848.51	0.005	0.95
Other				1,00

Table A1.5 Key categories analysis by level, including LULUCF, in 2016

IPCC source category	Gas	Emissions in 2016, kt CO_2-eq.	Share in total emissions in 2016	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	70 620.66	0.155	0.16
4.A.1 Forest Land Remaining Forest Land	CO_2	-64 877.16	0.143	0.30
4.B.1 Cropland Remaining Cropland	CO_2	47 246.31	0.104	0.40
2.C.1 Iron and Steel Production	CO_2	42 989.72	0.094	0.50
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	25 667.40	0.056	0.55

IPCC source category	Gas	Emissions in 2016, kt CO_2-eq.	Share in total emissions in 2016	Cumulative total of Column D
A	B	C	D	E
1.A.4 Other Sectors - Gaseous Fuels	CO_2	25 337.78	0.056	0.61
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	24 878.27	0.055	0.66
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	24 464.97	0.054	0.72
1.A.3.b Road Transportation	CO_2	22 694.40	0.050	0.77
1.B.1 Fugitive emissions from Solid Fuels	CH_4	16 347.07	0.036	0.80
3.A Enteric Fermentation	CH_4	10 752.01	0.024	0.83
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10 113.86	0.022	0.85
5.A Solid Waste Disposal	CH_4	8 231.30	0.018	0.87
1.A.3.e Other Transportation	CO_2	7 670.29	0.017	0.88
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	7 320.84	0.016	0.90
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	3 997.98	0.009	0.91
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	3 802.46	0.008	0.92
2.A.1 Cement Production	CO_2	3 622.85	0.008	0.92
5.D Wastewater Treatment and Discharge	CH_4	2 985.18	0.007	0.93
2.B.1 Ammonia Production	CO_2	2 662.89	0.006	0.94
2.A.2 Lime Production	CO_2	2 472.21	0.005	0.94
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	1 907.61	0.004	0.95
2.B.2 Nitric Acid Production	N_2O	1 877.17	0.004	0.95
2.C.2 Ferroalloys Production	CO_2	1 848.51	0.004	0.95
Other				1,00

Table A1.6. Key categories analysis by trend, excluding LULUCF, in 2016

IPCC source category	Gas	Emissions in 2016, kt CO_2-eq.	Share in total emissions in 2016	Cumulative total of Column D
A	B	C	D	E
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	70620.66	0.172	0.17
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	24464.97	0.091	0.26
1.A.4 Other Sectors - Gaseous Fuels	CO_2	25337.78	0.076	0.34
1.A.4 Other Sectors - Solid Fuels	CO_2	1743.49	0.074	0.41
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	3802.46	0.073	0.49
2.C.1 Iron and Steel Production	CO_2	42989.72	0.069	0.55
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	24878.27	0.067	0.62
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	128.75	0.051	0.67
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	7320.84	0.047	0.72
1.A.4 Other Sectors - Liquid Fuels	CO_2	128.48	0.039	0.76
1.A.3.e Other Transportation	CO_2	7670.29	0.031	0.79
5.A Solid Waste Disposal	CH_4	8231.30	0.028	0.82
1.B.1 Fugitive emissions from Solid Fuels	CH_4	16347.07	0.028	0.85
3.A Enteric Fermentation	CH_4	10752.01	0.027	0.87
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CH_4	25667.40	0.023	0.90
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	3997.98	0.010	0.91
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	1907.61	0.009	0.91

IPCC source category	Gas	Emissions in 2016, kt CO_2-eq.	Share in total emissions in 2016	Cumulative total of Column D
A	B	C	D	E
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10113.86	0.008	0.92
5.D Wastewater Treatment and Discharge	CH_4	2985.18	0.008	0.93
1.A.3.b Road Transportation	CO_2	22694.40	0.006	0.94
1.A.3.d Domestic Navigation - Liquid Fuels	CO_2	81.80	0.005	0.94
1.B.2.b Fugitive Emissions from Oil and Natural Gas - Natural Gas	CO_2	1760.20	0.005	0.95
1.A.4 Other Sectors - Solid Fuels	CH_4	120.49	0.004	0.95
1.A.3.c Railways	CO_2	424.93	0.004	0.95
Other				1,00

Table A1.7. Key categories analysis by trend, including LULUCF, in 2016

IPCC source category	Gas	Emissions in 2016, kt CO_2-eq.	Share in total emissions in 2016	Cumulative total of Column D
A	B	C	D	E
4.B.1 Cropland Remaining Cropland	CO_2	47246.31	0.161	0.16
4.A.1 Forest Land Remaining Forest Land	CO_2	-64877.16	0.099	0.26
1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels	CO_2	24464.97	0.090	0.35
1.A.1 Fuel combustion - Energy Industries - Solid Fuels	CO_2	70620.66	0.080	0.43
1.A.1 Fuel combustion - Energy Industries - Liquid Fuels	CO_2	3802.46	0.060	0.49
1.A.4 Other Sectors - Solid Fuels	CO_2	1743.49	0.059	0.55
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO_2	7320.84	0.042	0.59
1.A.4 Other Sectors - Gaseous Fuels	CO_2	25337.78	0.040	0.63
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO_2	128.75	0.040	0.67
1.B.1 Fugitive emissions from Solid Fuels	CH_4	16347.07	0.034	0.71
3.D.1 Direct N_2O Emissions From Managed Soils	N_2O	24878.27	0.033	0.74
1.A.4 Other Sectors - Liquid Fuels	CO_2	128.48	0.031	0.77
1.A.3.e Other Transportation	CO_2	7670.29	0.030	0.80
3.A Enteric Fermentation	CH_4	10752.01	0.029	0.83
2.C.1 Iron and Steel Production	CO_2	42989.72	0.021	0.85
5.A Solid Waste Disposal	CH_4	8231.30	0.016	0.87
4.D.1.1 Peat Extraction Remaining Peat Extraction	CO_2	145.93	0.016	0.88
4.G Harvested Wood Products	CO_2	707.96	0.015	0.90
1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO_2	10113.86	0.014	0.91
1.A.3.b Road Transportation	CO_2	22694.40	0.013	0.92
1.A.1 Fuel combustion - Energy Industries - Other Fossil Fuels	CO_2	1907.61	0.006	0.93
3.D.2 Indirect N_2O Emissions From Managed Soils	N_2O	3997.98	0.005	0.93
2.B.1 Ammonia Production	CO_2	2662.89	0.005	0.94
4.A.2 Land Converted to Forest Land	CO_2	-1455.09	0.004	0.94
4.C.1 Grassland Remaining Grassland	CO_2	115.79	0.004	0.95
1.A.3.d Domestic Navigation - Liquid Fuels	CO_2	81.80	0.004	0.95
5.D Wastewater Treatment and Discharge	CH_4	2985.18	0.004	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 1990-2016, 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:

$$B_{gfi} = FC_{fi} \bullet KB_{gfi}, \qquad (A1)$$

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:

$$B_{gi} = \sum_{f=1}^{F} B_{gfi}, \qquad (A2)$$

The total amount of emissions B_i under the *i* emission source category for all types of GHGs is determined as follows:

$$B_{i} = \sum_{g=1}^{G} B_{gi}, \qquad (A3)$$

The methodology for calculating emissions in category 1.a.3.a. "Civil Aviation" is characterized by a number of significant peculiarities and is presented in A2.7.

Peculiarity of the national inventory for this activity is the considerable difficulties to determine FC_{fi}, which is due to specifics of national statistics formation in the period of 1991 - 2016 and its consistency with IPCC definitions.

The key sources of information are the fuel and energy balance (FEB) of the Ukrainian SSR for 1990 [2], statistical reporting forms No. 4-MTP "Report on balances and use of energy materials and oil processing products" and No. 11-MTP "Report on results of fuel, heat, and electric-ity use" for years 1991-2016 (and their analogs for 1991-2002), provided by the State Statistics Committee of Ukraine.

A2.2 Sources of activity data

A2.2.1 Statistical reporting form No. 4-MTP "Report on balances and use of energy materials and oil processing products"

Form No. 4-MTP is the form of state statistical reporting on the balance and use of energy materials, fuels and lubricants in Ukraine. It is the main form for inventory of emissions from fossil fuel combustion.

However, there is still the major problem inherited from the era of the Soviet Union, which was not resolved when this form was developed - namely, the sectoral principle of energy statistics formation, not the technological one.

In accordance with the type of economic activity (TEA) of the consumer, in form No. 4-MTP all consumed fuel and lubricants, 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 and motor fuel categories, as noted - road and off-road transport, use of motor fuels in different types of economic activities - automotive, aircraft and the like, other activities.

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 State Statistics Service of Ukraine.

In the period of 1991-2016, 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 sector of the economy:

1. The 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 2.1) 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 form No. 4-MTP contains information on fuel consumption by the energy sector of the enterprise 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 CHPs;
- field 11 - fuel consumption for production of heat and electricity at combined heat and power plants (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 and 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"

From form No.11-MTP, section I "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 the structure of form No. 11-MTP changed significantly and does not contain data on fuel consumption.

A2.2.3 Fuel and energy balances of Ukraine

The FEB of Ukraine for 1990 was used to recalculate 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 State Statistics Service of Ukraine and the International Energy Agency in the next years cannot be properly applied for the purpose of GHG inventory, because they are based on form No.4-MTP and reflect the sectoral approach - direct use under TEA of data on final consumption, which includes the fuel consumption that does not actually relate to this activity type.

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 Table A2.1.

Table A2.1. Types of fuels used

#	Fuel	Groups of fuels*	Fuel code	
			2015	2016
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	Of these, briquettes from scobs	B	196	731
14	Biodiesel from oils, sugar and starch crops, and animal fats	B	198	782
15	Other types of source fuels	B	200	750,760,770,790

#	Fuel	Groups of fuels*	Fuel code	
			2015	2016
16	Coke and semi-coke from hard coal, gaseous coke	S	220	170
17	Hard, brown coal, and peat resins	S	225	200
18	Pitch and pitch coke	S	226	190
19	Aviation gasoline	L	230	450
20	Motor gasoline	L	240	430
21	Mixed motor fuel containing bio-ethanol ... 5-30%	B	245	435
22	Fuel for jet engines of the gasoline type	L	250	460
23	Oil distillates, other light fractions	L	260	510
24	White spirit and other special gasoline	L	261	511
25	Light oil distillates for production of motor gasoline	L	262	512
26	Fuel for jet engines of the kerosene type	L	270	470
27	Kerosene	L	280	480
28	Gas oils	L	300	440
29	Medium oil distillates, other medium fractions	L	310	520
30	Heavy fuel black oils	L	320	490
31	Petroleum oils, heavy oil distillates	L	330	530
32	Propane and butane, liquefied	L	430	540
33	Ethylene, propylene...	L	440	580
34	Petroleum jelly, paraffin...	L	450	560
35	Petroleum coke (including shale)	L	460	570
36	Petroleum bitumen (including shale)	L	470	550
37	Other types of oil products	L	500	650
38	Other fuel processing products	Oth	630	800
39	Coke oven gas produced as a byproduct	S	600	220
40	Blast furnace gas	S	610	230
41	Oxigen steel gas	S	620	240

** 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 category

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 (petrol, gas oil, etc, for the exception of liquefied propane and butane) were not accounted for the period of 1991-2016 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.

Energy use of lubricants is accounted for in CRF category 1.A.1 "Energy Industries", the rest of lubricants are transferred to subcategory 1.A.3.b.iv "Motorcycles".

As it is impossible to clearly determine the loss factor for certain categories of emission sources on the basis of national statistics (form 4-MTP, section 4), so this factor was calculated for Ukraine as a whole and adopted for all groups of consumers.

According to statistics lubricants include other heavy oil distillates; for that reason, energy use of lubricants is accounted for under category 1.A.1 "Energy industries", while the rest is reported under subcategory 1.A.3.b.iv "Motorcycles".

Activity data of fuel consumption by CRF category at stationary fuel combustion for 2016 are presented in Table A2.2.

Table A2.2. Activity data of fuel consumption at stationary fuel combustion for 2016 in accordance with CRF emissions 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 Public Power Plants	Form No.4-MTP total, Section 2, Column 8
1.A.1.aii Combined Heat and Power Plants (CHP)	Form No.4-MTP total, Section 2, Columns 9,10, 11;
1.A.1.aiii Boiler Plants	Form No.4-MTP total, Section 2, Column 12
1.A.1.b Oil Refining	Data on the total fuel consumption for oil refining by fuel types from form No.11-MTP (fuel)
1.A.1.c Solid Fuel Production and Other Activities in the Fuel and Energy Sector	Summary of: 1. Form No.4-MTP total, Section 2, Columns 13,14; 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.2. Manufacturing Industries and Construction	
1.A.2.a Iron and Steel, Ferro-Alloy Production	Form No.4-MTP kved, TEA Division 24 "Metallurgical Industry", Section, 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 Chemical Production	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: 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 "Industry", 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 Services and Public Administration	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 Households	Form No.4-MTP total, Section 3, Column 5
1.A.4.c Agriculture/Forestry/Fishery/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 2016 are presented in Table A2.3.

Table A2.3. Activity data of fuel consumption at mobile fuel combustion for 2016 in accordance with CRF emissions categories

CRF sub-category	Determining the volume of fuel burned	Fuel code
1.A.3.a Civil Aviation	The fuel volume on aircraft (AC) departures from airports situated in the territory of Ukraine	450 460 470
1.A.3.b Road Transport	The fuel volume according to surrogate method (see 3.2.9.2.2)	782 430 435 510 511 512 480 440 520 540
1.A.3.c Railway Transport	Form No.4-MTP kved, TEA Divisions 49.1, 49.2 "Railway transport", Section 3, Column 2	440
1.A.3.d Waterway Transport	Form No.4-MTP kved, TEA Division 50, "Waterway transport", Section 3, Column 2	440 490
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 Transport	The fuel volume according to surrogate method (see 3.2.9.2.5)	198 240 245 280 300 310

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 1990-2016 according to [1] within the exception of category 1.A.3.b "Domestic Aviation"; for NOx, CO, NMVOC and SO_2 - to CORINAIR 2013.

NCV values for most types of fuel for 1990-2016 in Ukraine in general were adopted based on state statistics of Ukraine (4-MTP, 11-MTP, TB of the Ukrainian SSR, the statistical compilation "Fuel and Energy Resources of Ukraine").

An exception is the NCV of 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). Also, for certain types of fuel where the NCV cannot be determined correctly, the default values were used [1]. 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 1A1ai, see A.2.6.2) are equal to 1.

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

Fuel	**Code**	**Carbon content factor**	**NCV**	**Fuel**	**Code**	**Carbon content factor**	**NCV**
Hard coal	110	25.8*	21.96	Fuel for jet engines of the gasoline type	460	19.65	43.04
Briquettes, pellets from hard coal	140	26.6	15.23	Oil distillates, other light fractions	510	19.65	43.04
Brown coal	120	27.6	8.63	White spirit and other special gasolines	511	20.0	40.20
Briquettes, pellets from brown coal	150	26.6	16.53	Light oil distillates for production of motor gasolines	512	20.0	40.20
Non-agglomerated fuel peat	130	28.9	10.28	Fuel for jet engines of the kerosene type	470	19.5	44.10
Briquettes, pellets from peat	160	28.9	14.66	Kerosene	480	19.6	43.80
Crude oil, including oil from bituminous materials	410	20	41.55	Gas oils	440	20.12	43.05
Gas condensate	415	17.5	37.97	Medium oil distillates, other medium fractions	520	20.12	43.05
Natural gas	310	15.21	48.75	Heavy fuel black oils	490	21.1	40.18
Charcoal	720	30.5	29.50	Petroleum oils, heavy oil distillates	530	20	39.81
Firewood	740	30.5	10.82	Propane and butane, liquefied	540	17.2	45.35
Fuel briquettes and pellets from wood and other natural materials	730	27.3	11.60	Ethylene, propylene, petroleum gases, other...	580	15.7	43.67
Briquettes from made of scobs	731	27.3	11.60	Petroleum jelly, paraffin...	560	20	43.36
Biodiesel from oils, sugar and starch crops	782	19.3	27.00	Petroleum coke (including shale)	570	26.6	31.65
Other types of source fuels	750,760, 770,790	27.3	29.31	Petroleum bitumen (including shale)	550	22	39.57
Coke and semi-coke from hard coal, gaseous coke	170	29.2	28.59	Other types of oil products	650	20	29.31
Hard, brown coal, and peat resins	200	22.0	28.00	Other fuel processing products	800	20	29.31
Pitch and pitch coke	190	29.2	28.20	Coke oven gas produced as a byproduct	220	12.1	35.22
Aviation gasoline	450	19.1	44.30	Blast furnace gas	230	70,91	4.13
Motor gasoline	430	19.65	43.04	Oxygen steel furnace gas	240	49,64	7.06
Mixed motor fuel containing bio-ethanol ... 5% -30%	435	19.65	43.04				

** - 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	Code of the fuel in form No. 4-MTP	Methane emission factors by fuel consumption domains, kg/TJ				
		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
Briquettes from made of scobs	731	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 resins	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				
Fuel for jet engines of the gasoline type	460					
Oil distillates, other light fractions	510	3				
White spirit and other special gasolines	511	3				
Light oil distillates for production of motor gasoline	512	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				

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
Propane and butane, liquefied	540	1	1	5	5	5
Ethylene, propylene, petroleum gases, other...	580	3	3	10	10	10
Petroleum jelly, paraffin...	560	3	3	10	10	10
Petroleum coke (including shale)	570	3	3	10	10	10
Petroleum bitumen (including shale)	550	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
Blast furnace gas obtained as a side- product in blast furnaces	230	1	1	5	5	5
Other gas (produced by coal gasification)	240	1	1	5	5	5
Combustible shale	006	1	10	300	10	300
Refinery gas, not liquefied	061	1	1	5	5	5
Refinery feedstock	054	3	3	10	10	10

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
Briquettes from made of scobs	731	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 resins	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				
Fuel for jet engines of the gasoline type	460					
Oil distillates, other light fractions	510	0.6				
White spirit and other special gasolines	511	0.6				
Light oil distillates for production of motor gasoline	512	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				

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
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 jelly, paraffin...	560	0.6	0.6	0.6	0.6	0.6
Petroleum coke (including shale)	570	0.6	0.6	0.6	0.6	0.6
Petroleum bitumen (including shale)	550	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
Combustible shale	230	1.5	1.5	1.5	1.5	1.5
Refinery gas, not liquefied	240	0.1	0.1	0.1	0.1	0.1
Refinery feedstock	006	0.6	0.6	0.6	0.6	0.6

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...	435		18.4				115
Jet gasoline-type fuel	460	see A2.7					
Oil distillates, other light fractions	510		18.4				115
White spirit and other special gaso-lines	511		18.4				115
Light oil distillates for production of motor gasolines	512		3.9				
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
Heavy fuel black oils	490				7		
Petroleum oils...	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 Avia-tion**	**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...	435		5.6				1.2
Jet gasoline-type fuel	460	see A2.7					
Oil distillates, other light fractions	510		5.6				1.2
White spirit and other special gaso-lines	511		5.6				1.2
Light oil distillates for production of motor gasolines	512		3.9				
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
Heavy fuel black oils	490				2		
Petroleum oils...	530		5.6				28.6
Propane and butane, liquefied	540		3				

A2.6 Determination of physical and chemical parameters of power-generating coals and natural gas

A2.6.1 Natural gas

The input data for determination of parameters of natural gas in the GTS of Ukraine 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" and PJSC "Ukr-gasvydobuvannya".

The component composition of natural gas is determined based on chromatographic analysis in line with [19], based on which the net calorific value of natural gas is estimated according to [20].

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:

$$k_c^{Av} = \frac{\sum_i \rho_i^{av} \cdot r_i^{av} \cdot \frac{M_C}{M_i}}{NCV^{av}}; \qquad (A4)$$

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 transit 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, 1990-2016

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

Parameter*	NCV	Carbon content	Density	CH_4	CO_2
Year	**GJ/t**	**tC/TJ**	**kg/m3**	**% vol.**	**% vol.**
2005	48.720	15.190	0.697	96.245	0.163
2006	48.720	15.220	0.697	96.245	0.163
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

** Determined for standard conditions (20°C, 101.3 kPa)*

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 0.8 %, 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.

Visible changes for all natural gas properties in 2015 and 2016 took place due decreasing of natural gas import along with stable natural gas extraction volumes in Ukraine.

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 [21] and implemented in current submission. Similar calculations for 2016 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 14 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) [22]. At the small Mironivska TPP the both bituminous and low-reactive coal are used, but their accounting is made separately.

Throughout the whole period of 1990-2016 the coal grades D, DG, G and Zh were received at thermal power plants burning bituminous coal, whereby the proportion of marks D and Zh was less than 5%. Grades A and P were received at TPPs burning low-reactive coal, while in different times and at different TPP the anthracite share ranged from 80 to 20%.

National standard DSTU 3472-96 "Lignite, bituminous coal and anthracite. Classification", according to which the supplies at thermal power plants were carried out for many years, determined to grade A volatile yield Vdaf < 8%, to grade P 8-18%, to grade D 33-46%, DG - 35-48% D - 35-50%. In practice, the frames of volatile yield values of coal for pulverized combustion at TPPs are determined by pulverized jet ignition, on the one hand, and by explosion safety conditions in pulverizing systems – on the other, and there are much narrower. For instance, DSTU 4083:2012 "Bituminous coal and anthracite for pulverized combustion in thermal power plants. Specifications" provides for boilers that burn low-reactive coal group the volatile yield limits no more than 15%, and for those that burn bituminous coal group - from 35 to 45%.

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 value is calculated from the analytical values of Ca, Aa, Wa obtained on samples enriched to ash content less than 10%. Cdaf includes non-volatile carbon, carbon of volatile matter and carbon of carbonate mineral matter. However, since the carbonate content in Ukrainian coal is usually less than 2%, according to GOST 27313-95 (ISO 1170-77) carbonate carbon is not considered separately.

Thus, used in subsequent calculations Cdaf values of thermal coal given in Ukrainian "Certificates of genetic, technological and qualitative characteristics" 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, % (for 4 years)
3	Statistical digest	Digests of quality, volume of coal mining and of coal processing products (annual) in 1991-2014	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%) (In a year)

According to the developed methodology [21] the mass of coal combusted is estimates as following:

$$B_{coal} = (B \cdot \frac{b_{coal}}{100}) \cdot (\frac{7000}{Q_i^r}), \text{ tonnes,} \quad (A5)$$

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:

$$NCV_{coal} = Q_i^r \cdot 4.187/1000, \text{ MJ/kg,} \quad (A6)$$

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, % (by reports of 3-tech-TPP); and can be 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 astimated 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 2003-2016 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, th. natural tones

TPP	Grade	1990	1995	2000	2005	2011	2012	2013	2014	2015	2016
Zmiyivska	A, P	4204	3111	1870	2140	2840	3139	3213	2382	552	1086
Tripilska	A, P	1911	1960	1407	1285	2270	2564	2148	1803	1311	1434
Vuglegirska	G, DG	1491	1963	1450	1725	2035	2596	1016	1608	2002	2241
Starobeshivska	A, P	3438	4033	2658	2232	2743	3035	3739	2721	2107	2211
Slovyanska	A, P	689	1159	1038	1303	1616	1346	1159	575	1075	1407
Luganska	A, P	2461	1238	2060	1937	2594	2747	2345	2128	1267	1606
Zuyivska	G, DG	1024	2668	2497	2441	3231	2629	3119	2087	1560	1776
Kurakhisvska	G, DG	4633	4855	2814	2662	3820	3424	3785	3303	3368	3504
Zaporizka	G, DG	3967	2891	2263	2074	2246	2165	2605	2482	2656	2366
Prydniprovska	A, P	2061	3104	1486	1756	1944	1986	1943	1907	794	1354
Kryvorizka	A, P	6539	4015	1510	1848	3402	3747	3236	3023	1241	2310

TPP	Grade	1990	1995	2000	2005	2011	2012	2013	2014	2015	2016
Ladyzhynska	G, DG	2854	3088	1818	1676	1740	2252	2823	2706	2746	2072
Burshtynska	G, DG	4523	4024	1892	3201	4391	4700	4748	4895	4845	4289
Dobrotvirska	G, DG	376	1037	1248	944	941	1139	972	912	1158	1164
Myronivska	G, DG	317	174	135	41	175	166	164	135	80	260
Myronivska	A, P	195	3	-	39	181	192	179	147	125	
Total	A, P	21498	18622	12030	12541	17589	18755	17962	14686	8472	11409
Total	G, DG	19186	20701	14116	14764	18579	19071	19231	18128	18415	17670
Totally in Ukraine		40684	39322	26146	27304	36168	37826	37193	32815	26888	29079

Table A2.12. NCV of coal supplied to TPPs in Ukraine, MJ/kg (as received)

TPP	Grade	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Zmiyivska	A, P	20.75	19.28	19.23	22.00	21.91	23.03	23.00	22.08	23.54	23.23
Tripilska	A, P	19.28	19.05	18.37	22.27	21.89	22.82	22.91	22.23	23.36	21.93
Vuglegirska	G, DG	18.07	17.77	19.40	20.70	21.45	22.57	22.51	22.71	22.39	22.35
Starobeshivska	A, P	20.22	20.86	18.31	19.82	21.95	22.55	22.02	23.17	23.15	23.30
Slovyanska	A, P	21.73	20.75	17.67	20.73	22.70	22.63	22.84	23.38	23.60	23.30
Luganska	A, P	18.16	19.24	18.41	24.23	23.90	24.43	25.03	24.94	23.17	23.51
Zuyivska	G, DG	16.22	16.08	16.43	20.06	19.75	19.22	20.22	20.34	20.73	19.85
Kurakhisvska	G, DG	14.89	15.47	15.39	18.55	17.88	17.67	18.87	17.93	17.94	17.38
Zaporizka	G, DG	17.03	15.77	16.45	19.85	21.85	21.09	22.14	21.32	21.11	21.02
Prydniprovska	A, P	21.13	19.56	18.37	20.96	23.72	22.56	23.09	23.31	22.32	23.47
Kryvorizka	A, P	21.51	18.59	18.41	21.53	24.74	24.35	24.15	24.28	23.35	24.03
Ladyzhynska	G, DG	14.74	13.98	12.90	19.78	20.76	20.73	21.32	20.39	20.40	20.91
Burshtynska	G, DG	16.70	16.90	16.63	19.14	20.53	21.33	21.56	21.31	20.76	20.74
Dobrotvirska	G, DG	18.74	17.69	15.47	21.42	21.31	22.44	22.46	21.99	20.81	21.01
Myronivska	G, DG	13.69	13.47	16.48	17.48	17.95	18.57	18.77	18.51	19.00	19.98
Myronivska	A, P	21.14	18.23	0.00	23.02	20.51	20.57	20.63	20.84	22.64	
Total	A, P	20.54	19.58	18.44	21.64	22.99	23.29	23.23	23.36	23.21	23.32
Total	G, DG	16.11	15.96	16.02	19.68	20.18	20.50	20.93	20.58	20.41	20.26
Totally in Ukraine		18.45	17.68	17.13	20.58	21.58	21.88	22.04	21.83	21.29	21.46

Table A2.13. Carbon content factor Kc of coal supplied to TPPs in Ukraine, t/GJ

TPP	Grade	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Zmiyivska	A, P	28.81	29.33	28.72	28.24	28.86	27.89	28.05	28.17	27.46	28.00
Tripilska	A, P	28.64	29.03	28.85	28.64	28.89	28.14	28.45	28.37	27.83	28.49
Vuglegirska	G, DG	26.14	26.22	25.43	25.16	25.38	24.73	25.00	25.13	25.10	25.14
Starobeshivska	A, P	27.90	28.12	28.13	28.61	28.76	28.26	28.60	28.00	27.59	27.66
Slovyanska	A, P	28.23	28.90	28.82	28.41	28.51	28.28	28.27	27.95	27.68	27.66
Luganska	A, P	29.37	28.06	28.91	27.19	28.13	28.14	28.23	28.04	28.48	28.21
Zuyivska	G, DG	27.02	27.06	26.63	25.56	25.89	25.70	25.61	25.60	25.38	25.73
Kurakhisvska	G, DG	26.39	26.77	25.99	25.90	26.27	25.92	25.62	26.14	26.06	26.27
Zaporizka	G, DG	26.75	26.59	25.83	25.33	25.17	25.35	25.45	25.68	25.32	25.30
Prydniprovska	A, P	28.82	29.52	28.92	28.67	28.21	28.22	28.27	28.05	28.38	27.81
Kryvorizka	A, P	27.79	28.25	28.33	27.64	27.21	27.23	27.29	27.23	27.59	27.10
Ladyzhynska	G, DG	27.74	26.52	26.14	25.83	25.68	25.97	26.39	26.45	26.16	25.49
Burshtynska	G, DG	27.41	26.65	25.99	25.65	25.54	25.39	25.58	25.68	25.75	25.92

TPP	Grade	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Dobrotvirska	G, DG	25.99	26.45	25.91	24.42	24.84	24.59	24.94	25.32	25.51	27.05
Myronivska	G, DG	27.64	27.96	26.46	25.75	25.92	25.09	25.34	25.53	25.73	26.84
Myronivska	A, P	28.80	30.45	-	27.65	27.90	27.60	27.83	27.61	28.04	28.00
Total	A, P	28.36	28.72	28.62	28.15	28.30	27.94	28.12	27.91	27.84	27.92
Total	G, DG	26.92	26.66	26.02	25.51	25.64	25.42	25.62	25.78	25.67	25.79
Totally in Ukraine		27.77	27.74	27.31	26.78	27.05	26.75	26.90	26.80	26.42	26.64

Table A2.14. Carbon oxidation factor Ko of coal at TPPs in Ukraine

TPP	Grade	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016
Zmiyivska	A, P	0.914	0.886	0.906	0.913	0.944	0.956	0.954	0.924	0.945	0.927
Tripilska	A, P	0.896	0.880	0.837	0.875	0.921	0.930	0.928	0.921	0.934	0.930
Vuglegirska	G, DG	0.994	0.993	0.996	0.997	0.997	0.998	0.998	0.998	0.997	0.997
Starobeshivska	A, P	0.898	0.899	0.906	0.850	0.922	0.954	0.949	0.957	0.956	0.958
Slovyanska	A, P	0.964	0.898	0.889	0.915	0.952	0.949	0.961	0.975	0.968	0.970
Luganska	A, P	0.851	0.784	0.774	0.944	0.948	0.954	0.955	0.952	0.936	0.936
Zuyivska	G, DG	0.992	0.993	0.991	0.995	0.995	0.996	0.997	0.997	0.997	0.997
Kurakhisvska	G, DG	0.955	0.968	0.959	0.976	0.977	0.976	0.977	0.976	0.976	0.974
Zaporizka	G, DG	0.994	0.992	0.992	0.994	0.996	0.995	0.996	0.996	0.995	0.995
Prydniprovska	A, P	0.900	0.908	0.873	0.902	0.930	0.895	0.898	0.903	0.901	0.915
Kryvorizka	A, P	0.966	0.947	0.955	0.958	0.949	0.956	0.949	0.938	0.918	0.933
Ladyzhynska	G, DG	0.988	0.987	0.983	0.995	0.996	0.995	0.996	0.995	0.995	0.996
Burshtynska	G, DG	0.988	0.988	0.980	0.979	0.983	0.985	0.987	0.986	0.986	0.984
Dobrotvirska	G, DG	0.980	0.974	0.964	0.980	0.982	0.986	0.987	0.987	0.983	0.983
Myronivska	G, DG	0.935	0.887	0.973	0.990	0.990	0.990	0.990	0.990	0.990	0.968
Myronivska	A, P	0.562	0.606	-	0.937	0.973	0.977	0.970	0.972	0.961	0.927
Total	A, P	0.917	0.899	0.876	0.909	0.939	0.945	0.944	0.937	0.940	0.940
Total	G, DG	0.982	0.984	0.981	0.987	0.989	0.989	0.990	0.990	0.989	0.989
Totally in Ukraine		0.943	0.937	0.926	0.948	0.961	0.965	0.965	0.963	0.971	0.968

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 years 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.

Thanks to the possibility of use cheap gas and oil, in 90-th years it was common practice to combust them not only at oil-gas boilers, but also together with coal at coal-firing units. Under such conditions, high ash content of coal was not only acceptable, but desirable in view of maintaining a protective layer of slag on the walls of the bottom part of the furnace. Ash content of coal in supplies to TPPs was reduced only since 2001-2002, due to above mentioned implementation of regulations on quality and of price scales that take into account the quality of the coal. Accordingly, since that time coal NCV has increased, together with the carbon content of coal on as-received base.

It should be noted that, due to the high volatile yield and greater reactivity of nonvolatile carbon, pulverized burning stable conditions of bituminous coal are provided at a lower NCV than of low-reactive coal. This stipulates generally lower NCV of bituminous coal than of low-reactive, and, together with lower carbon content on a dry ash free base, - less carbon content on as-received base in bituminous than in low-reactive coal.

However, accounting the higher hydrogen content in bituminous coals, the average specific carbon content on as-received base in relation to NCV is less than for low-reactive coal. NCV is less of high heat value by heat of steam condensation in products of combustion. With NCV increasing, when about equal moisture content, relative share of the subtrahend reduces, that's why the specific carbon content on as-received base per NCV (coal content factor) is also reduced.

On the other hand, due to above mentioned reasons carbon oxidation factor is significantly greater for bituminous coal than for low-reactive coal. For both grade groups, since 2001-2002 carbon oxidation factor increased due both to a decrease of oil-gas addition and to restore proper technical state of boilers, and stabilized at 0.94 for low-reactive and 0.99 for bituminous coal.

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 [27] and implemented in current submission.

According to the results of the research work, carbon content and NCV for gasolines, diesels 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, 2016 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 gasoline and diesel oil production industry data, fuel standards and expert knowledge of the refinery processing of fuel formulations that have made up the types of gasoline, diesel and LPG fuels made 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, diesels 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, NCV for different fuel types was estimated according to Mendeleev formula [27]:

$$NCV\ (MJ/kg) = 0.339*C+1.256*H-0.109*(O-S)-0.025*(W-9H); \qquad (A11)$$

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 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 "Average Fuel Brand Representative (AFBR)".

A similar model for LPG as for gasoline and diesel 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 characterised 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 by aircraft equipped with jet and turbojet engines

To assess GHG emissions by civil aviation aircraft equipped with jet and turbojet 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 included 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.

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 [23], 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 the EMEP/CORINAIR methodology [23], into energy ones, the net calorific value was used, which is 44.1 MJ/kg in accordance with [1].

When calculating emissions of CO_2, the carbon emission factor for jet fuel 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 the EMEP/CORINAIR methodology 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, fuel consumption and GHG emission data for which are presented in the EMEP/CORINAIR methodology, Tables A2.15-A2.21 were used.

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

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
B777	B788	Cassna	LJ24	F100	G280
BAC111	BA11	Cassna	LJ31	F100	GALX
BAC111	GLF2	Cassna	LJ35	F100	GL5T
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 - AN-225 "Mriya" is accounted for as 1.5 Boeing 747-400.
2 - The conversion factor of double-engine aircrafts into single-engine ones is 0.5.

Table A2.16. Departure statistics for domestic aviation in the period of 2007-2016.

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A310	2		1	1		4		1		1
A318					2	7	2	4	4	3
A319	116	102	70	68	77	156	122	26	21	9
A320	972	1691	1107	1070	1380	1091	215	63	28	49
A321					134	190	45	25		13
A332					1					
A343	1	3			1	1		1		2
AT43		2	12	12	7	1100	484	2		
AT45						1				
AT72	11 421	5 479	1826	1 765	1 759	5 244	7 561	3 407	2 203	2 702
B732	122	877				46	4			
B733	1 051	1 149	955	923	1 213	2 321	1 581	947	1 156	975
B734	1 622	2 172	1544	1 493	2 211	2 015	1 155	867	142	7
B735	1 337	2 361	2836	2 742	3 602	3 596	3 453	1 200	1 675	1 776
B737	1	1	3	3	3					1
B738	1	4	350	338	359	539	1 132	1 307	1 485	2 410
B742	57	39	35	34	36	37	32	96	34	20
B744	11	16	9	9	12	5	11	13	10	15
B752			1	1	1	2	11			
B762						3				
B763	2		4	4	5	17	50		2	2
BA11	8547	4947	1985	1919	1204	662	431	283	275	189
BE20	413	350	336	325	292	199	214	121	69	74
C130	74	77	76	73	75	49	40	34	59	48
C550	120	303	962	930	1 920	3 034	4 035	2 112	844	579
CRJ1			8	8	4	4				
CRJ2		224	502	485	566	548	657	214	63	17
CRJ9			2	2						
D228	1722	546	325	314	100	68	40	16	6	17
D328		1			2					
DC87	9	36	18	17	6	15	14	2		
DC94	6865	6159	414	400	13	33			2	
DH8D					4	1	2	1	2	1
E120	3		1	1						

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
E145	1 188	6 070	12842	12 415	8 928	6 586	4 681	3 708	2 947	2 854
E170					1	1	1	1		
E190			271	262	401	532	346	280	687	1435
F100	69	100	592	572	507	1590	778	123	159	74
F28	113	121	100	97	120	151	150	91	138	104
F2TH	1 383	1 875	2119	2 049	2 210	2 407	2 057	1 212	555	459
F50					698	123				
MD82	163	216	292	282	112	89	14	1		
MD83	53	46	183	177	49	92	83	31	14	60
PAY3	28	35	162	157	310	516	624	499	279	169
RJ85					576	71	18	17		
SB20		2	4	4	4	3	1			
SF34	78	3 053	3543	3 425	3 658	1 014	345	1 074	251	102
SW4	2	3							1	
T134	350	140	68	66	51	89	9	4		3
T154	26	2	4	4	4	4		1		

Table A2.17. Departure statistics for international aviation in the period of 2007-2016.

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A306	4		7	9	60	29	142	19	3	7
A310	55	65	16	20	77	140	94	39	95	151
A318	351	233	171	213	13	28	49	57	44	47
A319	2016	1895	2159	2686	2545	2893	4051	3489	2936	1796
A320	2317	3957	5058	6291	7916	8659	10604	7584	5004	5754
A321	357	823	1055	1312	3200	3954	4520	2441	705	2240
A332		7	2	2	5	7	191	243	93	160
A333			1	1		4	5	3	27	240
A343	6	29	5	6	7	5	5	83	27	21
A345					1			144		1
A346						1			1	
AT43	44	1032	925	1151	1525	1331	773	9	2	4
AT45	2	2	6	8	310	234	4	1	3	
AT72	2 438	1 488	762	948	899	1 256	806	377	542	309
B190	1	3			5		7	3		
B462	3	33	59	74	173	171	28	21	2	1
B712	1	1				8				
B721	3	1	2	2	1	2	1			
B722	5	2	2	2						
B732	416	218	2	2	2	1602	1659	1175		
B733	4 258	4 949	2733	3 399	4 218	4 731	3 751	2 554	2 332	3 816
B734	7 644	8 891	4404	5 478	5 936	5 355	2 871	1 073	472	724
B735	5 602	7 227	6552	8 149	9 324	9 365	7 789	4 751	4 762	4 155
B736	254	244	264	328	425	31				
B737	390	425	383	477	629				649	128
B738	1 533	1 994	3128	3 891	4 216	6 526	10 963	10 963	12 299	16 469
B742	297	320	171	213	143	103	83	51	37	38
B743	18	1	9	11	2	47	79	2		
B744	129	113	70	87	81	62	72	64	101	125
B752	213	270	181	225	300	807	1401	1007	2278	245
B753	11	12	15	19	12	14	13	14	19	26
B762	15	29	4	5	16	13	5	3		
B763	1120	1323	739	919	1319	1119	310	503	853	876
B772		9	2	3	2	3	3	1	3	7
B77W								1		
BA11	1047	517	148	184	126	142	88	81	45	58
BE20	128	129	88	109	112	103	96	39	47	47
C130	1081	1137	865	1076	1078	683	337	205	163	116
C550	695	872	853	1 061	1 401	1 640	1 612	1 061	606	477
CRJ1	229	230	68	84	72	80	85	65	28	44
CRJ2	1536	1310	999	1243	1220	2059	2157	813	303	327
CRJ9	410	681	778	968	541	568	903	591	398	703

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
D228	147	32	137	170	91	30	21	11	3	8
D328	4	3	3	4	3	1	1		3	1
DC85			1	1	2				1	
DC87	43	43	23	29	18	14	15	4	2	1
DC94	2317	1166	588	731	38	42	1	5	2	3
DH8A		2	3	4	11		5			
DH8C		1	1	1						
DH8D	285	249	292	363	1202	1308	981	958	759	832
E120	34	20	97	121	144	169	218	282	52	
E145	1 520	2 666	5390	6 704	6 715	5 026	3 083	2 523	2 052	2 087
E170	463	496	580	722	743	1080	979	1198	1356	1507
E190	4	85	1028	1279	1288	1470	2612	3678	4320	4392
F100	1053	1363	1862	2316	2944	2602	3045	1760	1693	1080
F27			10	12						
F28	110	106	95	118	154	219	283	117	131	98
F2TH	3 186	3 176	2281	2 837	3 105	3 466	3 275	2 116	1 497	1 670
F50	318	228	2	3	3	8			1	
JS31	1		2	2		3				
MD11			1	1		1		1	1	
MD82	1194	1496	731	909	667	212	27	17	4	3
MD83	322	343	93	116	232	209	505	351	181	635
PAY3	101	109	96	119	133	135	168	124	111	63
RJ85	29	5	9	11	446	231	69	229	155	234
SB20	529	1167	637	792	507	323	59			
SF34	324	433	280	348	249	374	311	315	329	340
SH36							1			
SW4	30	17	18	22	15	14	3		1	1
T134	2334	577	39	49	61	41	38	6		
T154	1583	1525	109	136	144	32	78	4	1	

Table A2.18. Statistics of distance flown by domestic aviation in the period of 2007-2016, thousand km

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A310	1.2	0.0	0.5	0.5	0.0	1.0	0.0	0.6	0.0	0.5
A318	0.0	0.0	0.0	0.0	1.5	2.3	1.3	2.2	1.9	1.5
A319	69.6	61.0	39.3	38.1	38.3	83.5	66.5	13.8	9.4	3.6
A320	586.2	1143.0	720.4	696.4	884.7	687.6	113.4	30.7	13.0	21.1
A321	0.0	0.0	0.0	0.0	83.8	122.5	24.2	14.7	0.0	5.7
A332	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
A343	0.7	2.1	0.0	0.0	0.2	0.6	0.0	0.4	0.0	1.1
AT43	0.0	1.0	3.5	3.5	2.2	573.8	307.2	0.9	0.0	0.0
AT45	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
AT72	6261.4	2802.3	912.4	881.9	927.2	2926.8	4270.5	1843.0	1077.7	1260.3
B732	74.3	600.7	0.0	0.0	0.0	26.8	2.7	0.0	0.0	0.0
B733	624.6	669.7	579.3	559.8	702.0	1353.1	946.3	453.6	532.5	444.8
B734	942.7	1232.7	953.1	921.6	1301.7	1124.8	678.7	438.4	64.4	2.9
B735	774.6	1205.7	1735.7	1678.1	2022.0	2097.1	2029.7	592.2	791.7	842.0
B737	0.7	0.5	1.2	1.2	1.9	0.0	0.0	0.0	0.0	0.5
B738	0.5	1.9	228.4	220.6	225.3	320.2	650.8	674.9	732.6	1156.6
B742	23.0	10.8	11.2	10.8	13.6	14.2	10.5	38.5	19.4	5.7
B744	4.1	6.9	1.5	1.5	2.8	1.5	3.6	3.1	0.7	2.2
B752	0.0	0.0	0.7	0.7	0.5	0.3	4.7	0.0	0.0	0.0
B762	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
B763	1.3	0.0	1.2	1.2	2.6	8.0	27.9	0.0	1.1	1.1
BA11	4298.0	2414.2	937.2	906.0	563.2	300.1	193.0	155.6	152.0	98.6
BE20	198.0	167.4	171.5	165.8	144.9	105.0	121.5	51.6	27.0	30.2
C130	25.9	30.7	21.1	20.3	29.6	15.2	12.2	9.9	13.7	12.0
C550	62.5	160.0	529.0	511.5	1063.2	1646.5	2160.3	1034.7	386.0	281.2
CRJ1	0.0	0.0	4.8	4.8	1.9	1.9	0.0	0.0	0.0	0.0
CRJ2	0.0	132.0	296.1	286.1	323.4	322.0	409.6	122.2	28.8	7.3

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CRJ9	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
D228	817.8	274.6	154.3	149.0	42.8	34.0	16.0	4.8	2.6	4.1
D328	0.0	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
DC87	5.4	18.6	9.4	8.9	4.0	7.2	6.8	1.1	0.0	0.0
DC94	3745.6	3446.5	251.2	242.7	5.0	16.1	0.0	0.0	0.3	0.0
DH8D	0.0	0.0	0.0	0.0	1.2	0.4	1.1	0.9	1.1	0.5
E120	2.1	0.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0
E145	641.8	3132.7	6751.9	6527.4	4502.9	3288.7	2354.8	1755.4	1453.8	1359.7
E170	0.0	0.0	0.0	0.0	0.3	0.2	0.5	0.5	0.0	0.0
E190	0.0	0.0	163.8	158.4	241.7	313.3	180.2	132.9	314.7	682.3
F100	34.8	51.4	307.8	297.4	261.9	679.1	391.4	46.9	49.3	26.2
F28	60.2	51.6	48.4	47.0	59.9	64.8	73.0	33.3	58.6	40.9
F2TH	692.7	985.8	1099.9	1063.6	1159.2	1315.2	1133.8	591.3	252.2	213.5
F50	0.0	0.0	0.0	0.0	379.1	67.1	0.0	0.0	0.0	0.0
MD82	86.9	127.6	190.4	183.9	52.0	57.8	9.6	0.0	0.0	0.0
MD83	27.7	22.9	114.5	110.8	21.0	53.6	40.1	13.2	6.4	25.9
PAY3	18.8	17.5	57.8	56.0	122.8	198.7	234.7	189.4	131.1	77.4
RJ85	0.0	0.0	0.0	0.0	319.5	41.2	9.6	9.6	0.0	0.0
SB20	0.0	1.1	1.0	1.0	0.8	0.8	0.7	0.0	0.0	0.0
SF34	40.7	1743.1	1758.3	1699.7	1907.0	567.1	175.7	537.9	107.2	32.6
SW4	1.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
T134	185.1	74.5	35.4	34.4	25.7	42.8	5.3	0.9	0.0	0.7
T154	14.1	1.0	0.9	0.9	1.5	0.2	0.0	0.6	0.0	0.0

Table A2.19. Statistics of distance flown by international aviation in the period of 2007-2016, thousand km

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A306	9.9	0.0	121.5	21.8	146.7	71.1	148.4	12.8	6.3	9.0
A310	165.8	179.7	278.0	62.4	172.5	248.6	162.9	52.7	101.0	232.9
A318	781.1	517.2	1132.2	475.2	30.0	66.9	107.5	127.1	107.6	98.9
A319	3301.9	2903.5	10472.9	4018.8	3790.1	4058.5	5406.9	5074.5	4401.1	2781.7
A320	4177.8	7364.1	32668.7	11984.9	15457.2	16613.4	18583.5	12588.7	8867.0	10192.9
A321	625.5	1355.1	6242.6	1664.0	5417.2	6468.7	7049.8	3752.1	856.1	3789.9
A332	0.0	15.4	38.5	5.2	15.1	17.1	424.6	618.9	121.2	371.1
A333	0.0	0.0	11.0	1.4	0.0	12.4	4.7	3.9	34.1	277.0
A343	8.8	53.1	146.7	22.2	13.9	11.2	10.0	195.9	72.2	32.2
A345	0.0	0.0	0.0	0.0	0.8	0.0	0.0	550.1	0.0	2.5
A346	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	1.7	0.0
AT43	44.2	997.0	1041.2	1035.1	1344.4	1168.0	682.2	14.8	2.6	5.2
AT45	0.7	0.7	4.0	2.9	194.3	148.5	5.3	0.4	3.7	0.0
AT72	2654.5	1614.9	2734.3	1058.8	929.9	1044.2	860.7	409.3	582.4	304.7
B190	0.8	4.3	0.0	0.0	8.6	0.0	8.1	4.2	0.0	0.0
B462	5.0	23.6	149.3	101.0	242.8	243.7	42.2	29.6	3.2	1.8
B712	2.3	0.4	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0
B721	10.3	2.2	23.0	4.4	4.2	3.6	6.5	0.0	0.0	0.0
B722	8.2	4.0	25.3	4.0	0.0	0.0	0.0	0.0	0.0	0.0
B732	437.7	206.7	10.6	2.6	4.3	2725.7	2252.3	1767.3	0.0	0.0
B733	7583.6	8453.3	16554.1	5825.3	7166.6	7666.7	6161.9	4149.3	3207.6	4187.0
B734	13289.7	15404.9	29950.4	9634.4	9832.6	8764.8	4950.6	1481.8	634.0	1138.2
B735	7804.0	9799.8	34015.9	11168.0	12728.3	12598.5	10075.5	6569.1	6119.0	4912.3
B736	248.5	263.5	971.2	331.0	423.2	35.3	0.0	0.0	0.0	0.0
B737	442.1	510.1	2100.3	771.9	950.9	0.0	0.0	0.0	1107.3	259.2
B738	1991.1	2669.5	20261.4	7155.1	8503.7	13356.4	22579.3	22755.7	24995.7	32931.0
B742	566.0	607.8	5510.7	490.8	356.2	225.3	202.4	134.3	74.8	82.9
B743	24.4	0.8	161.6	11.5	1.6	62.3	113.9	4.9	0.0	0.0
B744	405.6	348.8	2820.5	295.4	289.1	168.1	224.1	172.4	206.2	273.4
B752	527.4	677.7	2265.8	582.8	619.7	997.3	1680.2	1178.8	2335.4	356.4
B753	23.1	25.7	157.8	36.2	19.5	30.3	28.6	31.7	43.0	56.0
B762	31.4	63.9	57.5	11.3	36.2	33.1	11.8	3.6	0.0	0.0

Aircraft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
B763	7858.3	8576.9	32068.4	6793.9	8488.3	7213.7	1288.6	2951.5	4529.6	5850.9
B772	0.0	22.1	44.5	7.8	10.2	4.4	11.8	2.3	10.9	16.8
B77W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0
BA11	1056.4	489.3	450.8	175.8	116.3	144.3	88.9	81.8	46.3	76.2
BE20	163.7	159.4	62.2	134.4	143.9	120.5	116.5	44.8	57.0	70.7
C130	1659.2	1597.0	4590.5	1395.8	1326.2	776.7	368.3	343.2	254.7	193.0
C550	913.7	1141.0	932.5	1434.4	1931.7	2214.2	2156.4	1341.9	729.1	534.7
CRJ1	199.1	160.8	111.1	69.4	58.7	45.8	52.4	31.3	14.4	33.8
CRJ2	2390.6	1986.0	2198.9	1617.2	1450.6	2395.1	2279.1	680.9	293.6	333.7
CRJ9	842.0	1399.0	3138.4	1675.1	979.7	947.2	1245.2	738.8	420.7	820.1
D228	92.2	23.4	80.1	128.5	67.6	24.5	18.0	7.8	2.8	5.4
D328	7.3	5.3	7.5	6.2	4.0	0.7	0.4	0.0	3.1	1.2
DC85	0.0	0.0	22.6	3.5	12.4	0.0	0.0	0.0	1.8	0.0
DC87	100.8	84.4	264.4	55.8	41.1	38.6	27.5	8.7	4.4	1.8
DC94	3287.2	1738.6	4078.3	1041.2	67.2	70.1	1.8	5.3	3.4	6.5
DH8A	0.0	4.3	8.4	5.5	14.6	0.0	6.9	0.0	0.0	0.0
DH8C	0.0	0.6	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
DH8D	183.9	169.6	700.6	263.4	1069.2	1165.3	871.4	838.4	664.9	709.1
E120	19.7	8.9	152.7	50.5	67.5	79.1	97.2	125.3	23.1	0.0
E145	2263.4	3909.8	11634.8	8589.2	8010.3	6083.7	4661.0	3459.5	2922.7	2942.1
E170	398.7	453.1	1309.0	628.3	807.7	1134.2	912.1	951.4	1019.6	1164.9
E190	5.1	174.3	4720.5	2156.7	1888.9	1809.6	3861.2	5648.8	5994.1	5769.8
F100	1650.8	2008.5	8887.9	3354.0	4216.1	3722.3	4421.5	2519.5	2361.5	1529.6
F27	0.0	0.0	20.7	12.4	0.0	0.0	0.0	0.0	0.0	0.0
F28	217.4	187.1	368.4	170.3	241.8	353.0	407.7	184.9	189.0	148.7
F2TH	5106.5	4997.0	4539.2	4619.3	5144.4	5703.4	5447.9	3447.0	2373.0	2578.0
F50	421.4	281.0	6.3	5.4	2.8	13.9	0.0	0.0	1.2	0.0
JS31	0.8	0.0	1.2	1.4	0.0	4.2	0.0	0.0	0.0	0.0
MD11	0.0	0.0	19.6	1.7	0.0	1.4	0.0	2.0	1.7	0.0
MD82	2505.3	2899.5	5932.0	1755.1	1257.3	468.9	46.8	38.3	9.4	6.1
MD83	817.6	628.3	833.3	233.5	525.4	405.3	1005.0	679.8	286.0	1240.6
PAY3	133.6	120.0	33.9	135.7	147.1	166.8	162.4	98.7	89.3	55.7
RJ85	39.6	7.7	40.8	15.6	558.1	318.6	105.9	308.7	209.7	323.1
SB20	321.7	831.2	737.8	491.8	321.8	194.2	41.3	0.0	0.0	0.0
SF34	242.8	329.7	279.7	295.7	212.3	325.0	265.5	272.7	275.8	248.7
SH36	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
SW4	33.3	25.2	17.6	26.8	22.9	16.0	2.5	0.0	2.1	2.2
T134	2813.5	665.9	182.5	56.0	87.2	61.4	62.6	6.6	0.0	0.0
T154	2178.8	2023.7	1368.5	252.4	240.4	56.1	102.9	4.0	0.9	0.0

Table A2.20. Estimated fuel consumption by domestic aviation in 2007-2016, tones.

Air-craft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A310	10.9	0.0	5.2	5.2	0.0	14.2	0.0	5.4	0.0	5.2
A318	0.0	0.0	0.0	0.0	6.1	11.9	5.4	10.5	10.1	7.6
A319	323.4	284.7	190.0	175.7	184.8	396.8	303.8	67.1	50.4	17.6
A320	2953.4	5446.4	3495.8	3364.9	4313.7	3369.3	547.2	158.3	73.2	125.7
A321	0.0	0.0	0.0	0.0	503.0	725.2	145.7	89.3	0.0	39.3
A332	0.0	0.0	0.0	0.0	7.8	0.0	0.0	0.0	0.0	0.0
A343	8.2	24.6	0.0	0.0	2.0	7.7	0.0	6.4	0.0	14.5
AT43	0.0	1.4	6.1	5.8	3.1	808.2	384.6	1.3	0.0	0.0
AT45	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
AT72	22511.2	10167.6	3392.6	3165.6	3291.1	10503.1	14328.0	6591.7	3863.3	4632.3
B732	393.2	3015.6	0.0	0.0	0.0	144.7	13.0	0.0	0.0	0.0
B733	3074.6	3325.0	2826.2	2726.2	3493.7	6713.4	4412.9	2472.5	2958.5	2474.9
B734	4963.8	6554.1	4899.7	4734.3	6814.9	5991.9	3371.2	2448.7	377.2	16.8
B735	3956.0	6522.4	8643.3	8348.8	10466.2	10666.4	9791.7	3263.4	4461.5	4734.1
B737	3.1	2.6	7.1	6.0	8.9	0.0	0.0	0.0	0.0	2.6
B738	2.8	11.2	1142.3	1101.5	1147.4	1674.3	3303.4	3783.2	4209.9	6736.2
B742	524.1	268.3	308.7	251.5	300.3	324.8	235.2	825.3	378.7	145.0

Air-craft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
B744	93.6	150.3	29.9	50.1	85.4	37.2	81.3	82.0	40.3	78.4
B752	0.0	0.0	4.7	4.7	3.9	2.7	35.5	0.0	0.0	0.0
B762	0.0	0.0	0.0	0.0	0.0	16.9	0.0	0.0	0.0	0.0
B763	12.7	0.0	17.6	15.1	28.2	90.4	280.7	0.0	11.6	11.6
BA11	18211.7	10400.7	4212.2	3955.7	2450.4	1329.5	826.2	639.2	624.4	417.7
BE20	141.1	122.0	127.8	119.9	103.8	74.9	80.9	38.8	20.7	23.6
C130	118.1	139.3	116.2	91.3	132.1	65.1	50.8	42.1	57.1	49.8
C550	65.8	170.0	561.2	537.9	1109.1	1734.0	2171.9	1130.8	434.6	312.1
CRJ1	0.0	0.0	11.0	11.0	4.8	4.9	0.0	0.0	0.0	0.0
CRJ2	0.0	290.1	656.4	619.2	701.9	693.8	825.6	270.2	70.6	18.1
CRJ9	0.0	0.0	3.1	2.4	0.0	0.0	0.0	0.0	0.0	0.0
D228	758.9	250.0	146.7	138.9	41.2	30.8	14.9	5.5	2.6	4.5
D328	0.0	1.6	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0
DC87	52.3	195.0	98.5	90.3	36.6	73.2	64.6	11.1	0.0	0.0
DC94	25149.9	22924.0	1615.2	1545.6	38.3	106.4	0.0	0.0	1.9	0.0
DH8D	0.0	0.0	0.0	0.0	7.0	2.0	4.2	2.7	4.2	2.1
E120	5.3	0.0	1.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0
E145	1435.7	7203.4	15504.6	14875.9	10461.3	7640.7	5195.4	4187.7	3408.6	3199.8
E170	0.0	0.0	0.0	0.0	1.2	0.5	1.7	1.7	0.0	0.0
E190	0.0	0.0	637.9	614.5	941.1	1233.9	719.9	586.0	1413.0	3005.8
F100	158.2	233.2	1415.5	1329.2	1183.7	3396.6	1704.8	235.8	270.3	137.5
F28	234.4	222.2	209.6	193.6	233.4	276.8	277.7	154.8	256.4	186.2
F2TH	1231.7	1732.8	2006.5	1890.6	2052.5	2297.8	1877.7	1083.4	471.4	398.5
F50	0.0	0.0	0.0	0.0	1270.8	224.4	0.0	0.0	0.0	0.0
MD82	537.5	730.4	1083.4	1035.1	324.1	329.3	50.4	1.0	0.0	0.0
MD83	180.1	148.8	689.8	654.1	137.1	329.3	252.0	87.1	42.6	179.6
PAY3	8.3	7.3	26.4	23.5	50.7	85.7	97.9	81.7	51.9	31.4
RJ85	0.0	0.0	0.0	0.0	1395.7	172.2	39.8	39.9	0.0	0.0
SB20	0.0	2.1	2.7	2.7	1.8	2.0	1.2	0.0	0.0	0.0
SF34	51.0	2151.1	2222.4	2148.7	2389.6	700.0	201.7	674.7	133.8	40.1
SW4	1.2	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
T134	1033.0	412.9	204.6	188.6	142.5	246.6	27.1	3.7	0.0	2.8
T154	147.1	10.7	7.5	12.1	17.9	7.5	0.0	6.0	0.0	0.0

Table A2.21. Estimated fuel consumption by international aviation in 2007-2016, tones.

Air-craft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A306	70.8	0.0	17.0	156.2	1049.6	508.4	1179.8	125.1	45.8	71.7
A310	926.2	1015.8	49.9	347.4	1011.8	1520.6	933.8	344.1	705.0	1471.1
A318	2319.0	1536.3	381.5	1410.3	88.7	196.1	300.9	377.6	315.0	296.8
A319	10478.4	9384.9	3230.3	13071.7	12357.5	13469.0	17076.1	16641.8	14331.5	8992.4
A320	14366.8	25159.0	9636.0	40760.3	52315.6	56437.7	59886.2	44137.2	30629.1	35210.3
A321	2710.0	5946.9	1338.0	7774.1	23680.5	28478.2	29250.7	16746.2	4044.8	16567.0
A332	0.0	117.0	5.2	38.4	108.7	127.6	3018.5	4596.0	1055.6	2806.2
A333	0.0	0.0	1.4	11.0	0.0	86.6	41.4	32.0	284.4	2381.4
A343	81.5	467.9	18.5	177.0	120.7	94.9	80.6	1651.2	597.3	295.1
A345	0.0	0.0	0.0	0.0	8.1	0.0	0.0	4058.1	0.0	19.4
A346	0.0	0.0	0.0	0.0	0.0	33.4	0.0	0.0	19.8	0.0
AT43	54.3	1233.6	831.9	1296.2	1689.4	1468.9	796.0	17.2	3.1	6.2
AT45	1.3	1.3	2.2	5.4	301.4	229.4	6.6	0.8	5.0	0.0
AT72	8569.9	5214.5	851.1	3407.4	3015.6	3502.5	2570.5	1320.3	1880.3	994.9
B190	0.6	2.9	0.0	0.0	5.7	0.0	5.8	2.9	0.0	0.0
B462	18.1	101.3	80.5	374.6	898.1	899.2	143.5	108.7	11.8	6.6
B712	7.3	2.2	0.0	0.0	0.0	57.1	0.0	0.0	0.0	0.0
B721	51.2	11.6	4.4	23.0	20.3	19.4	31.0	0.0	0.0	0.0
B722	53.4	25.4	4.0	25.3	0.0	0.0	0.0	0.0	0.0	0.0
B732	1879.1	916.8	2.6	10.6	16.0	10397.0	8477.1	6907.8	0.0	0.0
B733	26727.4	30041.1	4683.9	20701.1	25530.5	27515.6	20836.4	14888.8	11919.7	16519.1

Air-craft type	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
B734	51788.3	60057.0	7745.5	37449.2	38604.1	34496.2	17959.6	6013.6	2585.5	4509.5
B735	29355.1	37114.1	8979.4	42191.3	48121.9	47814.7	36266.2	24765.3	23516.4	19346.1
B736	915.2	939.9	266.4	1206.6	1549.6	123.8	0.0	0.0	0.0	0.0
B737	1645.8	1868.3	619.8	2622.5	3285.1	0.0	0.0	0.0	3711.4	838.8
B738	7694.7	10231.5	5752.1	25413.6	29661.8	46440.5	72896.1	78823.0	86906.5	114768.8
B742	8164.7	8773.8	394.0	6861.4	4925.8	3179.6	2598.2	1842.6	1067.7	1168.7
B743	396.7	14.9	9.4	198.7	30.0	1017.4	1701.4	73.6	0.0	0.0
B744	5170.8	4365.0	237.6	3908.3	3634.8	2122.3	2630.0	2111.5	2719.8	3484.3
B752	2562.7	3286.1	468.8	2815.2	3099.1	5565.3	8858.7	6672.6	13733.1	1909.7
B753	125.6	139.6	28.6	200.1	111.1	164.2	143.0	170.3	231.1	303.5
B762	202.0	407.9	9.0	71.9	230.0	207.6	68.9	26.1	0.0	0.0
B763	46150.9	50632.7	5463.2	39786.3	50123.7	42599.3	7289.1	17556.1	27144.6	34477.2
B772	0.0	190.3	5.2	66.6	81.0	42.2	88.3	19.7	88.5	145.0
B77W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	0.0	0.0
BA11	3329.8	1579.6	141.4	567.2	380.2	454.3	264.0	256.3	144.8	226.7
BE20	93.6	91.7	108.5	77.5	82.5	69.3	65.2	26.0	33.0	39.5
C130	6691.0	6485.1	1122.1	5700.7	5441.2	3201.6	1404.7	1378.5	1027.5	772.1
C550	747.3	934.8	1153.2	1167.0	1567.0	1801.3	1632.0	1104.8	606.8	452.8
CRJ1	393.7	345.6	56.2	140.5	119.1	107.2	113.7	79.6	35.4	68.9
CRJ2	3887.6	3248.4	1299.8	2744.5	2516.8	4174.3	3840.4	1317.7	542.9	604.1
CRJ9	1917.0	3185.8	1346.3	3928.3	2278.8	2233.5	2837.5	1848.3	1097.6	2084.9
D228	75.8	18.2	103.6	99.4	52.6	18.3	13.0	6.2	2.0	4.2
D328	11.0	8.1	4.7	10.0	7.0	1.8	1.6	0.0	6.3	2.2
DC85	0.0	0.0	3.5	22.6	76.3	0.0	0.0	0.0	12.6	0.0
DC87	575.0	503.1	44.3	334.8	236.7	213.1	159.9	50.6	25.6	11.0
DC94	16068.3	8413.9	837.5	5088.8	316.9	333.9	7.7	28.0	16.3	29.4
DH8A	0.0	7.4	4.2	11.2	30.0	0.0	13.9	0.0	0.0	0.0
DH8C	0.0	2.0	0.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0
DH8D	650.3	581.5	211.9	871.7	3173.6	3456.1	2479.1	2508.9	1988.6	2151.1
E120	57.7	31.9	40.5	190.2	232.6	272.8	341.3	450.2	83.0	0.0
E145	3717.8	6435.1	6905.7	14517.9	13791.4	10453.6	7347.8	5773.5	4836.0	4884.5
E170	1041.1	1157.0	504.7	1635.5	1943.6	2763.5	2189.4	2575.6	2828.5	3182.0
E190	14.9	461.4	1733.5	5944.6	5345.8	5354.3	10228.6	15844.9	17204.5	16846.4
F100	5231.9	6431.2	2696.5	10789.1	13603.7	12038.2	13455.1	8133.5	7685.4	4971.1
F27	0.0	0.0	10.3	25.0	0.0	0.0	0.0	0.0	0.0	0.0
F28	570.8	500.0	137.1	475.3	663.6	964.2	1096.3	504.1	524.1	409.4
F2TH	6356.1	6245.1	3714.0	5734.2	6358.2	7065.6	6257.4	4275.4	2955.7	3220.8
F50	824.8	570.2	3.6	9.4	6.5	24.5	0.0	0.0	2.4	0.0
JS31	0.6	0.0	1.4	1.2	0.0	3.0	0.0	0.0	0.0	0.0
MD11	0.0	0.0	1.7	19.6	0.0	16.8	0.0	21.8	19.6	0.0
MD82	10434.0	12217.4	1411.5	7395.3	5319.0	1935.3	188.6	158.0	38.4	25.7
MD83	3541.5	2840.7	187.2	1041.5	2307.8	1817.2	4160.4	3050.4	1325.4	5558.0
PAY3	62.0	49.8	109.4	50.9	51.2	61.2	58.7	62.4	33.5	23.5
RJ85	127.9	24.2	12.7	50.0	1834.1	1026.0	313.0	998.7	678.0	1040.4
SB20	604.0	1489.4	395.6	917.8	596.9	366.6	69.9	0.0	0.0	0.0
SF34	289.5	392.2	237.9	347.8	249.3	381.3	291.0	319.9	324.1	297.7
SH36	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
SW4	27.2	19.5	21.9	21.5	17.6	0.0	2.2	0.0	1.6	1.6
T134	11275.2	2709.5	44.6	228.8	330.9	228.8	214.2	27.1	0.0	0.0
T154	15991.2	15007.4	202.3	1718.4	1679.5	387.1	718.7	32.7	7.8	0.0

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 substitute parameter for estimation of fuel consumed the passenger flow data were used. 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 [2], where in this indicator is explicitly specified. 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. a 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:

$$Q_{T_{CO2}} = C_{CO_2} \cdot \rho_{CO_2} \cdot K_T \cdot P_T \cdot 10^3, \qquad \text{(A15)}$$

where: $Q_{T_{CO2}}$ - 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:

$$Q_{T_{CH4}} = C_{CH_4} \cdot \rho_{CH_4} \cdot K_T \cdot P_T \cdot 10^3, \qquad \text{(A16)}$$

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 $C_{CH_4}, \rho_{CH_4}, C_{CO_2}, \rho_{CO_2}, K_D$ were applied (the values are shown in Table A2.22) were natural gas transportation volumes through main pipelines. These data are presented in the publication of the State Statistics Committee of Ukraine - "The Statistical Yearbook of Ukraine". Information available for the entire time series of 1990-2016.

The leakage volume was calculated on the basis of statistical reporting form 4-MTP, field 3 of section 5 (which corresponds to loss of gas in transit) and field 1, section 4 (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 2003-2016 and the available data for 1990-2002. based on expert assessments [24, 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:

$$Q_{D_{CO2}} = C_{CO_2} \cdot \rho_{CO_2} \cdot K_D \cdot P_D \cdot 10^3, \qquad \text{(A17)}$$

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:

$$Q_{D_{CH4}} = C_{CH_4} \cdot \rho_{CH_4} \cdot K_D \cdot P_D \cdot 10^3, \qquad (A18)$$

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 3, section 5 (which corresponds to natural gas losses in its consumption) and field 1, section 4 (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 2003-2016 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 A2.22. Parameters of natural gas transportation and distribution in Ukraine, 1990-2016

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
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

**-expert estimation*

A2.9 Activity data

The array of estimated data on energy use of fuels in CRF category Energy Industries 1.A for 2016 is presented in tables A2.23, A2.24.

Table A2.23. Fuel use by IPCC categories in physical units (stationary combustion) in 2016, tonnes

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/Fishing
Hard coal	32542310.17	0.0	456414,22	2217694.16	185284.15	4826.39	342.28	36821.89	1168746.35	8251.76	110386.58	711707.02	13158.89
Briquettes, pellets from hard coal	5834.26	0.0	50.80	0.0	0.0	0.0	0.0	8.30	840.00	35.10	829.77	70.00	11.80
Brown coal	7980.30	0.0	680.30	0.0	0.0	0.0	0.0	22.60	165.30	224.30	188.60	18.60	0.0
Briquettes, pellets from brown coal	3904.80	0.0	0.0	0.0	0.0	204.00	0.0	0.0	0.0	11.70	57.70	2518.00	118.00
Non-agglomerated fuel peat	35537.53	0.0	67.00	6952.57	0.0	0.0	0.0	0.90	12831.58	34746.78	106.61	3177.91	0.0
Briquettes, pellets from peat	98316.43	0.0	536.02	10.05	0.0	0.0	9.45	1222.76	4923.49	536.53	19612.15	60543.41	512.94
Crude oil, including oil from bituminous materials	0.0	0.0	2681.69	0.0	0.0	56.17	0.0	0.0	0.0	17.24	0.0	0.0	0.0
Gas condensate	18163.71	0.0	535593.40	0.0	0.0	167.00	0.0	0.0	0.0	53.55	0.0	0.0	150.40
Natural gas	8164910.94	21254.34	735182,37	1277190.22	140897.17	188967.02	15605.83	133449.4 5	346884.29	586742.58	563322.49	8602228.37	123947.42
Charcoal	473.80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.30	10.80	0.0	0.0
Firewood	989408.98	0.0	26832.26	534.59	0.0	937.65	1257.48	15601.31	2918.5	91103.30	135480.81	1320976.65	53400.20
Fuel briquettes and pellets from wood and	226275.92	0.0	1036.30	45.00	0.0	678.00	1621.30	6152.66	14486.93	3097.80	14215.00	2888.60	4000.90

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
other natural materials													
Biodiesel from oils, sugar and starch crops	0.0	0.0	0.0										
Other types of source fuels	1161341.73	0.0	41463.05	59752.76	0.0	210.40	0.0	26390.21	7423.07	9500.66	3423.28	41329.78	24208.72
Coke and semi-coke from hard coal, gaseous coke	159.62	0.0	46.09	0.0	59.96	1648.12	0.0	7570.87	23578.67	210490.38	42.30	0.0	666.03
Hard, brown coal, and peat resins	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2151.16	0.0	2151.16	0.0	0.0	0.0
Pitch and pitch coke	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.20	0.0	2.20	0.0	0.0
Aviation gasoline													
Motor gasoline	5.80	0.0	535.78										
Motor fuel composite with bioethanol ... 5% - 30%	0.0	0.0	10.10										
Fuel for jet engines of the gasoline type													
Oil distillates, other light fractions	209.13	0.0	0.0										

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
White spirit and other special gasolines	0.0	0.0	0.0										
Light oil distillates for production of motor gasoline	0.0	0.0	0.0										
Fuel for jet engines of the kerosene type			0.20										
Kerosene	0.0	0.0	33.40										
Gas oils	1415.16	0.0	20439.18										
Medium oil distillates, other medium fractions	8124.93	0.0	0.0										
Heavy fuel black oils	647767.39	20672.46	1503.20	880.30	0.0	0.0	0.0	241.40	1538.01	5790.04	6005.20	0.0	1217.70
Petroleum oils, heavy oil distillates	0.0	0.0	0.0										
Propane and butane, liquefied	22.97	0.0	1282.91	166.88	55.72	174.40	419.56	1821.92	837.62	3018.48	6366.01	13768.28	8511.93
Ethylene, propylene, petroleum gases, other...	0.0	0.0	112.10	0.0	0.0	1.0	0.0	23.80	6.30	104.50	0.10	0.0	0.0
Petroleum jelly, paraffin...	0.0	0.0	0.0	0.0	0.0	3.80	0.0	0.0	0.30	48.80	0.0	0.0	0.0

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
Petroleum coke (including shale)	707.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.00	0.0	0.0	0.0
Petroleum bitumen (including shale)	0.0	0.0	0.0	0.0	0.0	27.40	0.0	73.87	9213.54	15684.53	5995.01	0.0	13.10
Other types of oil products	30904.71	52972.13	211.10	56.50	0.0	0.0	0.0	164.80	184.30	600.90	1471.90	0.0	73.70
Other fuel processing products	805793.10	0.0	1171.89	0.00	239.54	491.45	0.0	193.58	41922.05	31838.81	2922.50	0.0	415.30
Coke oven gas produced as a byproduct	629025.94	0.0	512932.99	1158519.63	0.0	0.0	0.0	5995.77	8074.30	34281.88	3060.30	0.0	0.0
Blast Furnace Gace	2542720.0	0.0	0.0	0.0	0.0	0.0	0.0	84935.0	0.0	1498.0	4813.0	0.0	0.0
Oxygen steel furnace gas	222699.0	0.0	0.0	83688.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A2.24. Fuel use by IPCC categories in physical units (mobile combustion) in 2016, tonnes

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 materials					
Gas condensate					
Natural gas					991552.7
Charcoal					
Firewood					
Fuel briquettes and pellets from wood and other natural materials					
Briquettes from made of scobs					
Biodiesel from oils, sugar and starch crops		41.50			55.82
Other types of source fuels					
Coke and semi-coke from hard coal, gaseous coke					
Hard, brown coal, and peat resins					
Pitch and pitch coke					
Aviation gasoline	14357.4				
Motor gasoline		2416534.94			61310.06
Motor fuel composite with bioethanol ... 5% - 30%		670.78			3.06
Fuel for jet engines of the gasoline type					
Oil distillates, other light fractions		0.00			752.39
White spirit and other special gasolines		0.00			4.60
Light oil distillates for production of motor gasoline		0.00			
Fuel for jet engines of the kerosene type	27051.3				

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
Kerosene		780.27			1169.94
Gas oils		3756539.28	133795.17	18326.21	1448130.70
Medium oil distillates, other medium fractions		0.00			6260.47
Heavy fuel black oils				7591.65	
Petroleum oils, heavy oil distillates					2021.52
Propane and butane, liquefied		1098188.13			
Ethylene, propylene, petroleum gases, other...					
Petroleum jelly, paraffin...					
Petroleum coke (including shale)					
Petroleum bitumen (including shale)					
Other types of oil products					
Other fuel processing products					
Coke oven gas produced as a byproduct					
Blast Furnace Gas					
Oxygen steel furnace gas					

A2.10 Other matters related to activity data in Energy sector in 2014-2016

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[13]. 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 - 2016.

In order to ensure compliteness 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" [26], status of which is "confidential".

Revaluation of data for 2015, 2016 was also performed using the results of the study [26], as well as, indicative trends and socio-economic parameters in 2015,2016.

Main principles of the data revaluation are presented below.

2014 year. To estimate the activity data that were not included in nataional 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 analysed 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 potencial underestimation (PUL) of activity data in official data sources. At the stage 3 scientifically based decreasing coefficients (DC) for all potencial 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 analysed 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 potencial 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 approach.

2015 year. 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, 2016 were used for different IPCC 2006 categories according to alternative national and international data sources.

[13] 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

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	110687.58	1393.13	5671.54	0.00	235.82	0.0076	117988.08
1991	94725.80	1147.55	5016.39	0.00	188.20	0.0191	101077.96
1992	91695.63	1064.10	4320.85	0.00	142.35	0.0305	97222.96
1993	74550.79	809.70	3662.54	0.00	143.57	0.0591	79166.66
1994	63223.84	628.23	2976.58	0.00	161.22	0.0649	66989.95
1995	54917.44	519.37	2370.74	0.00	178.06	0.0677	57985.68
1996	52789.56	502.24	2778.20	0.00	143.24	0.0696	56213.31
1997	58099.28	587.18	3054.92	6.43	146.99	0.128	61894.94
1998	56701.93	598.13	2459.18	13.02	120.64	0.194	59893.10
1999	59159.95	638.23	2633.97	14.14	101.81	0.307	62548.41
2000	63310.89	698.79	3005.28	15.75	115.74	0.421	67146.87
2001	67044.94	1464.65	2928.35	29.04	112.08	0.463	71579.52
2002	68535.14	2193.47	3579.39	64.27	98.66	1.070	74472.00
2003	71209.95	2873.93	3815.51	105.22	77.15	1.991	78083.77
2004	74053.20	3665.84	3264.40	187.31	93.34	3.078	81267.16
2005	73295.70	3130.25	3765.06	285.17	142.33	4.467	80622.97
2006	77594.47	3046.32	3801.67	402.41	111.16	4.274	84960.32
2007	83454.82	3028.88	4946.64	561.22	154.71	5.198	92151.46
2008	81796.22	1711.28	4482.69	647.48	174.24	9.338	88821.25
2009	64758.41	695.66	2203.16	663.94	53.95	9.366	68384.49
2010	69642.62	1124.14	2934.70	744.09	26.67	9.710	74481.92
2011	73715.35	2579.32	3724.32	820.40	0.00	8.414	80847.81
2012	70766.31	2196.90	3491.63	841.34	0.00	10.990	77307.16
2013	67968.30	951.57	2605.90	881.85	0.00	12.543	72420.16
2014	58051.92	683.58	2264.50	848.40	0.00	16.726	61865.13
2015	53362.73	596.50	1697.46	775.59	0.00	19.397	56451.68
2016	54457.21	646.82	2022.44	889.00	0.00	24.111	58039.58

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**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Cement production, kt	22729.10	21744.50	20121.10	15011.60	11434.70	7626.80	5020.60	5101.00	5591.20	5828.10	5311.40	5786.30	7156.50	8922.70
Clinker production, kt	17455.70	16559.20	16084.60	11879.00	9267.30	6339.20	4027.40	4510.50	5215.40	4742.79	4239.06	4647.77	5291.62	6784.10
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	0.524	0.524	0.523	0.522	0.522	0.522
Correction factor for CKD, p.u.	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
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	0.5345	0.5345	0.5335	0.5324	0.5324	0.5324
CO_2 emissions, kt	9400.94	8918.12	8678.92	6397.55	4990.99	3407.57	2160.78	2415.37	2787.52	2534.92	2261.37	2474.65	2817.47	3612.12
SO_2 emission factor, kg/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
SO_2 emissions, kt	6.8187	6.5234	6.0363	4.5035	3.4304	2.2880	1.5062	1.5303	1.6774	1.7484	1.5934	1.7359	2.1470	2.67681
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Cement production, kt	10647.84	12164.54	13739.18	15018.83	14918.20	9503.37	9472.12	10579.64	9842.70	9856.50	8854.35	8848.75	9098.70	
Clinker production, kt	8117.40	9181.00	10522.00	11757.40	11981.30	5038.30	5583.90	7484.60	6279.198	6404.20	6064.639	6062.925	6687.396	
Emission factor, tons of CO_2/ton of clinker	0.515	0.511	0.511	0.514	0.515	0.504	0.506	0.511	0.512	0.520	0.533	0.530	0.531	
Correction factor for CKD, p.u.	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	
Implied emission factor, tons of CO_2/ton of clinker	0.5253	0.5212	0.5212	0.5243	0.5253	0.5141	0.5161	0.5212	0.5226	0.5304	0.5440	0.5406	0.5417	
CO_2 emissions, kt	4264.07	4785.32	5484.27	6164.16	6293.77	2590.08	2881.96	3901.12	3281.46	3396.78	3299.19	3277.51	3622.85	
SO_2 emission factor, kg/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	
SO_2 emissions, kt	3.19435	3.64936	4.121754	4.505649	4.47546	2.851011	2.84163	3.17389	2.95281	2.95695	2.65	2.65	2.72	

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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Lime dust correction factor (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
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
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
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
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
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
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
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

Continuation of Table A3.1.1.3

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Amount of lime produced, kt	4895.90	5301.67	5341.74	5450.25	5687.77	5127.97	4100.74	4241.08	4578.70	4482.50	3968.30	3183.80	3022.35	3324.90
Amount of quick lime, kt	2202.10	2384.61	2719.18	2671.66	2811.51	2407.59	2403.38	2494.77	4101.10	4047.80	3739.50	2884.89	2758.35	2946.66
Amount of slaked lime, kt	2693.80	2917.06	2622.56	2778.59	2876.25	2720.38	1697.36	1746.31	477.60	434.70	228.80	298.91	264.00	378.24
Amount of calcium quick lime, kt	1871.79	2026.92	2311.30	2270.91	2389.78	2046.45	2042.87	2120.55	3485.94	3440.63	3178.58	2452.15	2344.59	2504.66
Amount of dolomite quick lime, kt	330.32	357.69	407.88	400.75	421.73	361.14	360.51	374.22	615.17	607.17	560.93	432.73	413.75	442.00
Amount of slaked lime in dry mass, kt	1939.54	2100.28	1888.24	2000.58	2070.90	1958.67	1222.10	1257.34	343.87	312.98	164.74	215.22	190.08	272.33
Amount of lime in dry mass, kt	4141.64	4484.89	4607.42	4672.24	4882.41	4366.26	3625.48	3752.11	4444.97	4360.78	3904.24	3100.10	2948.43	3218.99
Amount of CaO in quick calcium lime, kt	1787.55	1935.71	2207.29	2168.72	2282.24	1954.36	1950.94	2025.13	3329.07	3285.80	3035.54	2341.81	2239.09	2391.95
Amount of MgO in quick calcium lime, kt	26.20	28.38	32.36	31.79	33.46	28.65	28.60	29.69	48.80	48.17	44.50	34.33	32.82	35.07
Amount of CaO in quick dolomite lime, kt	184.98	200.31	228.41	224.42	236.17	202.24	201.88	209.56	344.49	340.02	314.12	242.33	231.70	247.52
Amount of MgO in quick dolomite lime, kt	130.47	141.29	161.11	158.30	166.58	142.65	142.40	147.82	242.99	239.83	221.57	170.93	163.43	174.59
Amount of CaO and MgO in quick lime, kt	1454.65	1575.21	1416.18	1500.44	1553.18	1469.01	916.57	943.01	257.90	234.74	123.55	161.41	142.56	204.25
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
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
Lime dust correction factor (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
CO_2 emissions from calcium quick lime, kt	1455.70	1576.35	1797.51	1766.10	1858.55	1591.54	1588.75	1649.17	2711.03	2675.80	2472.00	1907.05	1823.41	1947.89
CO_2 emissions from dolomite quick lime, kt	269.62	291.96	332.93	327.11	344.23	294.78	294.26	305.45	502.12	495.60	457.85	353.21	337.72	360.78
CO_2 emissions from slaked lime, kt	1164.74	1261.27	1133.94	1201.40	1243.63	1176.23	733.90	755.07	206.50	187.95	98.93	129.24	114.15	163.54
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
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
Total CO_2 emissions, kt	2890.05	3129.58	3264.38	3294.61	3446.41	3062.55	2616.92	2709.68	3419.66	3359.35	3028.77	2389.51	2275.28	2472.21
Total emission factor, t/t	0.698	0.698	0.709	0.705	0.706	0.701	0.722	0.722	0.769	0.770	0.776	0.771	0.772	0.768

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
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
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
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
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
Use of soda in glass production, kt	166.17	166.38	157.47	145.93	123.61	117.60	91.10	76.13	73.30	75.99	75.36	201.94	199.87	180.72
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
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
CO_2 emissions from use of soda, kt	68.96	69.05	65.35	60.56	51.30	48.81	37.81	31.59	30.42	31.53	31.27	83.81	82.95	75.00
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
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
CO_2 emissions from glass production, kt	173.23	173.20	160.59	143.06	120.96	114.55	88.35	73.99	71.08	73.23	73.09	196.62	200.10	181.79
CO_2 emission factor for glass production, t/t	0.174	0.175	0.176	0.176	0.176	0.175	0.180	0.178	0.179	0.180	0.179	0.187	0.184	0.184
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
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Total glass production, kt	999.05	993.02	1090.96	1218.02	1328.01	988.05	1190.22	1434.95	1377.747	1364.436	1316.39	1181.29	1231.49	
Limestone use, kt	74.40	74.15	81.55	91.44	100.75	76.17	91.60	112.62	107.42	106.35	103.35	92.54	96.57	
Dolomite use, kt	157.61	156.46	171.80	191.40	207.61	153.22	184.73	220.47	212.41	210.39	202.89	182.27	189.91	
Limestone and dolomite use, kt	232.02	230.61	253.35	282.85	308.36	229.39	276.33	333.08	319.83	316.74	306.24	274.81	286.49	
Use of soda in glass production, kt	181.84	179.24	199.35	221.82	245.78	182.51	217.76	262.71	254.87	253.13	239.85	217.35	226.88	
CO_2 emissions from use of limestone, kt	32.74	32.63	35.88	40.25	44.34	33.52	40.32	49.23	46.28	45.50	44.46	40.39	42.18	
CO_2 emissions from use of dolomite, kt	75.27	74.88	82.34	91.93	99.46	73.31	88.25	104.05	99.68	99.27	95.17	87.33	91.76	
CO_2 emissions from use of soda, kt	75.46	74.38	82.73	92.06	102.00	75.74	90.37	109.03	105.77	105.05	99.54	90.2	94.16	
CO_2 emission factor for limestone use, t/t	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.437	0.431	0.428	0.430	0.436	0.437	
CO_2 emission factor for dolomite use, t/t	0.478	0.479	0.479	0.480	0.479	0.478	0.478	0.472	0.469	0.472	0.466	0.479	0.483	
CO_2 emissions from glass production, kt	183.47	181.89	200.95	224.23	245.80	182.57	218.94	262.30	251.73	249.82	239.17	217.75	227.91	
CO_2 emission factor for glass production, t/t	0.184	0.183	0.184	0.184	0.185	0.185	0.184	0.183	0.183	0.184	0.182	0.184	0.185	
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	
NMVOC emissions from glass production, kt	4.50	4.47	4.91	5.48	5.98	4.45	5.36	6.46	6.20	6.13	5.92	5.32	5.54	

Table A3.1.1.5 Greenhouse gas emissions from carbonate use (CRF category 2.A.4.a Ceramics)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Ceramics production, kt	6373.46	5202.02	4902.82	4591.59	4267.19	3985.11	3730.43	3808.91	3910.67	3985.83	4061.39	4100	4373.33	4800.11
Emission factor from ceramics production, t/t	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754
CO_2 emissions from ceramics production, kt	111.77	91.22	85.98	80.52	74.83	69.88	65.42	66.79	68.58	69.90	71.22	71.90	76.69	84.18
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Ceramics production, kt	5666.2	5865.63	6365.78	7184.51	6880.34	3661.69	3447.1	3975.03	3568.945	3822.23	4038.214	3949.01	3871.57	
Emission factor from ceramics production, t/t	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	0.01754	
CO_2 emissions from ceramics production, kt	99.36	102.86	111.63	125.99	120.65	64.21	60.45	69.71	62.59	67.03	70.81	69.25	67.89	

Table A3.1.1.6 Greenhouse gas emissions from carbonate use (CRF category 2.A.4.b Other Soda Ash Use)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Amount of soda ash used, kt	720.033	625.12	684.93	443.770	532.19	357.39	145.37	221.62	191.57	185.57	239.89	113.88	153.0	123.37
CO_2 emission factor, t/t	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415
CO_2 emissions, kt	298.81	259.42	284.24	184.16	220.85	148.32	60.32	91.97	79.50	77.013	99.55	47.26	63.52	51.199
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Amount of soda ash used, kt	220.36	253.26	211.40	226.35	254.01	140.75	108.00	138.31	98.37	52.44	34.79	6.25	20.27	
CO_2 emission factor, t/t	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	0.415	
CO_2 emissions, kt	91.450	105.107	87.73	93.93	105.41	58.41	44.82	57.40	40.826	21.76	14.44	2.59	8.41	

Table A3.1.1.7 Greenhouse gas emissions from Ammonia Production (CRF category 2.B.1)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Amount of ammonia produced, kt	4863.90	4603.60	4719.30	3916.50	3539.50	3776.30	4017.20	4132.20	3984.00	4541.20	4351.30	4500.00	4488.60	4674.40
Natural gas consumption of, mln m3	6122.5476	5841.0937	6193.6565	5003.9750	4697.8722	4687.2946	5179.1550	5062.3066	4809.0764	5387.3959	5138.8962	5297.4191	5254.5684	5491.3449
Carbon content in natural gas, t/TJ	15.18	15.18	15.18	15.18	15.18	15.18	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	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	3.6667	3.6667	3.6667	3.6667	3.6667	3.6667
Urea production, kt	2678	2756	2671	2511	2592	2702	2972	2808	2347	3015	3291	3258	3232	3490
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	0.733	0.733	0.733	0.733	0.733
CO_2 emission factor, t/t	1.9332	1.9184	2.0243	1.9051	1.9308	1.7834	1.8548	1.7797	1.8125	1.7191	1.6415	1.6581	1.6488	1.6370
CO emission factor, t/t	0.000006	0.000006	0.000006	0.000006	0.000006	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	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	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	0.00003	0.00003	0.00003	0.00003	0.00003
CO_2 emissions, kt	9402.9155	8831.7366	9553.4814	7461.4610	6833.9246	6734.5032	7451.1490	7353.9921	7221.1029	7806.7515	7142.4758	7461.4029	7400.7107	7651.8607
CO emissions, kt	0.0292	0.0276	0.0283	0.0235	0.0212	0.0227	0.0241	0.0248	0.0239	0.0272	0.0261	0.0270	0.0269	0.0280
NMVOC emissions, kt	0.4378	0.4143	0.4247	0.3525	0.3186	0.3399	0.3615	0.3719	0.3586	0.4087	0.3916	0.4050	0.4040	0.4207
NO_x emissions, t/t	4.8639	4.6036	4.7193	3.9165	3.5395	3.7763	4.0172	4.1322	3.9840	4.5412	4.3513	4.5000	4.4886	4.6744
SO_2 emissions, kt	0.1459	0.1381	0.1416	0.1175	0.1062	0.1133	0.1205	0.1240	0.1195	0.1362	0.1305	0.1350	0.1347	0.1402

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Amount of ammonia produced, kt	4717.10	5217.50	5152.20	5142.90	4892.00	3037.61	4166.12	5261.96	5049.41	4237.12	2983.93	2640.647	2044.20
Natural gas consumption of, mln m3	5483.1217	5862.7091	5747.9875	5627.3098	5412.8268	3530.1028	4724.4701	5876.5076	5661.0519	4677.6674	3225.9762	2779.1304	
Carbon content in natural gas, t/TJ	15.18	15.19	15.22	15.16	15.17	15.2	15.17	15.12924	15.14023	15.16761	15.1214	15.2137	15.260
Net calorific value of fuel combustion, TJ/mln m^3	0.03340	0.03340	0.03340	0.03340	0.03364	0.03340	0.03340	0.03396	0.03409	0.03413	0.03394	0.03457	0.03453
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
Urea production, kt	3619	3866	3742	3807	3593	3171	3005	3961	3888	2929	2154.1	2127	2042
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	0.733	0.733	0.7330	0.7330
CO_2 emission factor, t/t	1.5989	1.5475	1.5474	1.4891	1.5318	1.3984	1.5784	1.5521	1.5571	1.5886	1.5051	1.4393	1.3026
CO emission factor, t/t	0.000006	0.000006	0.000006	0.000006	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	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	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	0.00003	0.00003	0.00003	0.00003
CO_2 emissions, kt	7542.0205	8073.9157	7972.4868	7658.5198	7493.7142	4247.8115	6575.7378	8166.9227	7862.2471	6731.2582	4491.1118	3800.794	2662.892
CO emissions, kt	0.0283	0.0313	0.0309	0.0309	0.0294	0.0182	0.0250	0.0316	0.0303	0.0254	0.0179	0.0158	0.0123
NMVOC emissions, kt	0.4245	0.4696	0.4637	0.4629	0.4403	0.2734	0.3750	0.4736	0.4544	0.3813	0.2686	0.2377	0.1840
NO_x emissions, t/t	4.7171	5.2175	5.1522	5.1429	4.8920	3.0376	4.1661	5.2620	5.0494	4.2371	2.9839	2.6406	2.0442
SO_2 emissions, kt	0.1415	0.1565	0.1546	0.1543	0.1468	0.0911	0.1250	0.1579	0.1515	0.1271	0.0895	0.0792	0.0613

Table A3.1.1.8 Greenhouse gas emissions from Nitric Acid Production

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Nitric acid production, kt	2700.0	2386.80	2073.60	1760.40	1447.20	1134.00	1344.00	1471.00	1198.0	1295.00	1452.00	1407.00	1715.00	1726.0
N_2O emission factor, t/t (Medium pressure units)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)
N2O 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)	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	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	6.557	7.923	7.913
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	14.07	17.15	17.26
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Nitric acid production, kt	1482.60	1757.40	1761.20	2294.50	2121.20	1451.81	1796.00	2309.53	2336.96	1791.12	1569.40	1157.02	1399.83	
N_2O emission factor, t/t (Medium pressure units)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (CS)	0.007 (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)	
N2O 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)	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	0.01	0.01	
N_2O emissions, kt	6.888	8.124	8.161	10.561	9.744	6.599	8.048	10.57	10.757	8.073	7.112	5.21	6.29	
NO_x emissions, kt	14.83	17.57	17.61	22.95	21.21	14.52	17.96	23.09	23.37	17.91	15.69	11.57	13.99	

Table A3.1.1.9 Greenhouse gas emissions from Adipic Acid Production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
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
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
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
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
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
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
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
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	0.820611
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
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
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Amount of adipic acid produced, kt	65.8	48.7	52.1	58.3	29.3	4.2	52.9	61.49	13.002	Not producted				
N_2O emission factor, t/t	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					
Thermal use factor	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					
NMVOC emission factor, t/t	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					
N_2O emissions, kt	0.879417	0.650876	0.6963	0.7792	0.3916	0.0561	0.707	0.8218	0.173771					
NO_x emissions, kt	0.5264	0.3896	0.4168	0.4664	0.2344	0.0336	0.4232	0.4919	0.104016					
NMVOC emissions, kt	2.84914	2.10871	2.2559	2.5244	1.2687	0.1819	2.2906	2.6625	0.562986					
CO emissions, kt	0.02632	0.01948	0.0208	0.0233	0.0117	0.0017	0.0212	0.0246	0.005201					

Table A3.1.1.10 Greenhouse gas emissions from Petrochemical Production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
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	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	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	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	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	0.294	0.294
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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	0.645	1.071
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	1.29	2.142
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	317.422	442.359
Total CH_4 emissions, kt	10.270	8.735	6.808	4.797	4.508	2.403	1.880	2.467	2.507	1.909	1.693	31.530
Total NMVOC emissions, kt	0.684	0.637	0.484	0.342	0.637	0.342	0.265	0.372	0.436	0.295	0.294	0.739
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	10.3218	10.9828

Continuation of Table A3.1.1.10

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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	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	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	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	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	0.294	0.294	0.294	0.294	0.294
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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	0.004	0.004	0.004	0.004
NOx emissions for carbon black, kt	0.8955	1.29	1.5015	1.7385	1.6035	1.8135	1.617	0.8805	1.1355	0.8803	1.2898	1.1775	1.0561	0.8280	1.081
CO emissions for carbon black, kt	1.791	2.58	3.003	3.477	3.207	3.627	3.234	1.761	2.271	1.7606	2.5797	2.355	2.1123	1.6560	2.162
Total CO_2 emissions, kt	679.86	786.38	899.97	866.65	917.15	919.37	579.81	216.98	334.74	657.90	606.76	236.35	199.73	144.62	188.88
Total CH_4 emissions, kt	59.393	84.871	114.91	93.759	88.443	85.063	36.993	1.902	17.136	73.922	59.008	8.558	2.073	1.5842	2.069
Total NMVOC emissions, kt	1.131	1.291	1.579	1.388	1.402	1.442	0.813	0.446	0.599	1.263	0.787	0.116	0.050	0.0389	0.051
Total SO_2 emissions, kt	9.7751	12.145	15.098	17.084	15.863	17.655	15.756	9.3459	13.39	15.198	14.280	12.330	6.7526	5.7986	6.326

Table A3.1.1.11 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**
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
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
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
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
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
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
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
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
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
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Steel production, kt	38718.5	38615.5	40891.8	42828.5	37082.3	29848.0	32681.8	34762.0	32497.9	32673.02	27144.06	22997.61	22997.61	
Specific pig iron consumption for steel production, t/t	0.759	0.769	0.775	0.772	0.789	0.805	0.794	0.776	0.803	0.819	0.823	0.842	0.848	
Specific scrap consumption for steel production, t/t	0.328	0.330	0.329	0.323	0.328	0.297	0.297	0.329	0.301	0.288	0.282	0.263	0.253	
Carbon content in steel, %	0.213	0.213	0.213	0.213	0.213	0.210	0.212	0.212	0.210	0.211	0.211	0.210	0.210	
CO_2 emission factor, t/t	0.117	0.122	0.123	0.122	0.125	0.128	0.126	0.123	0.12748	0.12451	0.12831	0.13334	0.13313	
CO_2 emissions, kt	4547.5	4711.3	5028.0	5244.0	4646.4	3816.4	4119.4	4286.5	4142.9	4068.1	3482.9	3066.4	3221.3	
NO_x emissions, kt	0.37	0.38	0.41	0.43	0.41	0.38	0.44	0.52	0.44	0.49	0.42	0.32	0.34	
CO emissions, kt	0.07	0.07	0.08	0.08	0.07	0.07	0.08	0.09	0.09	0.09	0.07	0.06	0.07	
NMVOC emissions, kt	0.41	0.41	0.43	0.46	0.38	0.22	0.27	0.27	0.21	0.22	0.19	0.16	0.15	
SO_2 emissions, kt	0.0795	0.0830	0.0900	0.0980	0.0942	0.0803	0.1048	0.1280	0.0922	0.1162	0.0999	0.0732	0.0732	

Table A3.1.1.12 Greenhouse gas emissions from Iron Production (CRF category 2.C.1.2)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
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	27633.3
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	42991.6
Carbon content in iron, %	4.37	4.43	4.45	4.40	4.40	4.50	4.45	4.29	4.26	4.30	4.29	4.32	4.38
Carbon content in iron, kt	1963.33	1622.80	1573.08	1192.75	887.93	809.93	793.50	884.43	891.90	989.42	1102.47	1139.55	1210.34
Use of coke for iron production, kt	23586.9	19653.1	19152.6	15766	12927.5	11400.9	11140.2	12562.2	12201.6	12825.9	14108.1	14737.5	15196.6
Carbon content in coke, %	85.29	85.23	85.17	85.11	85.05	84.99	84.94	84.88	84.82	84.76	84.76	84.8	84.94
Use of coal for iron production, kt	0.00	0.00	0.00	0.00	0.00	47.50	34.60	19.50	49.70	52.00	46.30	47.7	31.10
Carbon content in coal, %	0.00	0.00	0.00	0.00	0.00	71.95	71.95	71.95	71.95	71.95	71.78	72.3	74.93
Use of natural gas for iron production, mln m^3	5.55	5.32	5.10	4.89	4.69	4.49	4.30	4.12	3.95	3.79	3.63	3.48	3.33
CO_2 emission factor when natural gas is used, t $CO_2/10^3$ m^3	1.847	1.849	1.849	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850
CO_2 emission factor at iron production, t/t	1.48	1.51	1.53	1.65	1.84	1.82	1.79	1.74	1.66	1.58	1.55	1.58	1.56
CO_2 emissions, kt	66571.25	55476.03	54052.45	44837.15	37068.74	32694.18	31883.88	35912.17	34815.46	36377.97	39932.78	41804.27	42980.78
Emissions of CH_4 (iron), kt	40.43466	32.96889	31.815	24.3972	18.16227	16.19856	16.04835	18.5544	18.84303	20.70882	23.12883	23.740	24.8699
Emissions of CH_4 (sinter), kt	4.64819	3.78996	3.65731	2.80459	2.08785	1.85715	1.82231	2.16334	2.27654	2.57550	2.84505	2.99613	3.10714
NO_x emissions, kt	3.414482	2.784039	2.6866	2.06020	1.533702	1.3678784	1.355194	1.566816	1.5911892	1.7487448	1.9531012	2.0047	2.10013
CO emissions, kt	58.40562	47.62173	45.955	35.2404	26.23439	23.39792	23.18095	26.8008	27.21771	29.91274	33.40831	34.292	35.92329
NMVOC emissions, kt	4.49274	3.66321	3.535	2.7108	2.01803	1.79984	1.78315	2.0616	2.09367	2.30098	2.56987	2.6378	2.76333
SO_2 emissions, kt	89.8548	73.2642	70.7	54.216	40.3606	35.9968	35.663	41.232	41.8734	46.0196	51.3974	52.3974	55.2666

Continuation of Table A3.1.1.12

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Iron production, kt	29529.0	30977.6	30746.1	32929.3	35649.7	30991.3	25683.1	27365.8	28877.0	28486.6	29088.7	24800.9	21862.8	23559.5
Sinter production, kt	44935.6	48134.0	48582.8	49002.8	51216.8	44553.1	35863.3	39492.6	40219.6	42598.0	43624	38294.601	33575.718	34383
Carbon content in iron, %	4.39	4.40	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.31	4.42	4.49	4.45
Carbon content in iron, kt	1296.32	1363.01	1383.57	1481.82	1604.24	1394.61	1155.74	1231.46	1299.46	1281.89	1254.45	1096.7	981.6	1049.14
Use of coke for iron production, kt	15405.9	15669.4	14955.8	16235.4	17713.4	17884.10	15624.0	15990.821	16126.9219	15661.86	15456.933	13417.59	12536.7	12872.72
Carbon content in coke, %	84.85	84.59	84.94	85.02	84.85	84.94	84.85	84.85	85.2	85.3	84.8	84.2	84.2	84.9
Use of coal for iron production, kt	66.10	115.40	161.90	140.40	170.70	101.97	126.66	151.20	154.20	139.28	117.75	110.01	91.29	108.79
Carbon content in coal, %	75.72	77.73	78.34	78.95	79.57	80.18	80.79	80.44	79.8	80.5	77.9	76.3	77.6	79.6
Use of natural gas for iron production, mln m3	3.41	3.47	3.47	2.89	2.64	1.899	1.67	1.57	1.896	1.757	1.701	3.4487	1.54	1.35
CO_2 emission factor when natural gas is used, t CO_2/103 m3	1.850	1.850	1.851	1.855	1.848	1.862	1.852	1.849	1.874	1.883	1.888	1.872	1.919	1.922
CO_2 emission factor at iron production, t/t	1.47	1.42	1.37	1.38	1.39	1.64	1.74	1.67	1.60	1.57	1.51	1.52	1.62	1.55
CO_2 emissions, kt	43365.8	43938.3	41977.7	45590.7	49730.04	50889.21	44749.37	45683.62	46076.51	44721.55	43820.07	37732.37	35350.74	36545.95
Emissions of CH_4 (iron), kt	26.5761	27.8798	27.6715	29.6364	32.08473	27.89217	23.11479	24.62922	25.9893	25.63794	26.17983	22.32081	19.676	21.203
Emissions of CH_4 (sinter), kt	3.14549	3.36938	3.40080	3.43020	3.58518	3.11872	2.51043	2.76448	2.81537	2.98186	3.05368	2.68062	2.35030	2.406
NO_x emissions, kt	2.2442	2.35429	2.33670	2.50262	2.70937	2.35533	1.951915	2.0798008	2.194652	2.1649816	2.2107412	1.8848684	1.6615	1.790
CO emissions, kt	38.3877	40.2709	39.9699	42.8081	46.34461	40.28869	33.38803	35.57554	37.5401	37.03258	37.81531	32.24117	28.42164	30.627
NMVOC emissions, kt	2.9529	3.09776	3.07461	3.29293	3.56497	3.09913	2.56831	2.73658	2.8877	2.84866	2.90887	2.48009	2.18628	2.356
SO_2 emissions, kt	59.058	61.9552	61.4922	65.8586	71.2994	61.9826	51.3662	54.7316	57.754	56.9732	58.1774	49.6018	43.7256	47.119

Table A3.1.1.13 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
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
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
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
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
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Ferroalloys Production, kt	1912.3	1632.4	1709.6	1867.9	1662.8	1200.7	1671.3	1419.6	1300	1142.219	1362.473	1092.131	1188.349	
CO_2 emission factor, t/t	1.59	1.60	1.61	1.69	1.71	1.61	1.68	1.60	1.64	1.67	1.76	1.73	1.55	
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	
CO_2 emissions, kt	3043.30	2608.87	2755.29	3164.35	2849.91	1938.97	2801.74	2264.65	2132.67	1909.01	2396.61	1920.44	1848.51	
CH_4 emissions, kt	0.242	0.157	0.122	0.167	0.154	0.159	0.155	0.111	0.089	0.152	0.132	0.093	0.051	

Table A3.1.1.14 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
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
CF4 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
C2F6 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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
CO_2 emissions, kt	195.84	201.60	200.16	201.89	200.79	89.38	44.84							
CF4 emissions, kt	0.0108	0.0165	0.0129	0.0180	0.0202	0.0063	0.0031	Not producted						
C2F6 emissions, kt	0.0011	0.0017	0.0013	0.0018	0.0020	0.0006	0.0003							

Table A3.1.1.15 Greenhouse gas emissions from Lubricant Use

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Total consumption, TJ	20783.400	20783.400	15597.600	12904.200	9969.600	9125.400	19336.200	22793.400	16232.077	14094.208	12660.672	12452.738	12109.599	11733.435
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
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
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
Emissions of CO_2, kt	304.826	304.826	228.767	189.263	146.222	133.840	283.600	334.306	238.073	206.717	185.692	182.642	177.609	172.092
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Total consumption, TJ	12594.624	12939.853	11619.786	14260.484	12667.338	9833.077	9735.318	10233.336	10105.130	9422.723	8619.209	7998.647	7834.641	
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	
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	
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	
Emissions of CO_2, kt	184.723	189.786	170.425	209.156	185.789	144.220	142.786	150.090	148.210	138.201	126.416	117.315	114.909	
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	

Table A3.1.1.16 Greenhouse gas emissions from Paraffin Wax Use

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Total consumption, TJ	8375.457	8354.36	4648.125	1708.456	1068.48	970.022	365.221	119.079	72.8774	84.082	733.798	633.242	736.036	743.672
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
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
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
Emissions of CO_2, kt	122.841	122.532	68.173	25.058	15.671	14.227	5.357	1.746	1.069	1.233	10.763	9.288	10.795	10.907
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Total consumption, TJ	707.667	634.319	628.441	597.167	610.286	266.232	722.759	674.391	737.228	781.633	829.323	716.494	703.223	
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	
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	
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	
Emissions of CO_2, kt	10.379	9.303	9.217	8.758	8.951	3.905	10.601	9.891	9.891	11.464	12.163	10.509	10.314	
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	

Table A3.1.1.17 Greenhouse gas emissions from product uses as substitutes for ozone-depleting substances

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Domestic refrigeration, kt $CO_{2\text{-eq}}$				2.330	12.978	19.504	25.785	27.995	32.476	36.445
Comercial refrigeration, kt $CO_{2\text{-eq}}$				4.459	0.310	10.584	21.750	33.802	46.634	57.435
Industrial refrigeration, kt $CO_{2\text{-eq}}$					1.271	5.948	8.697	19.248	36.913	77.846
Transport refrigeration, kt $CO_{2\text{-eq}}$				0.199	0.372	0.468	0.902	1.815	2.590	3.588
Comercial air conditioning, kt $CO_{2\text{-eq}}$						0.034	0.125	0.182	0.544	1.110
Mobile air conditioning for automotive vehicles, kt $CO_{2\text{-eq}}$		0.512	0.855	1.742	4.730	9.578	17.288	33.561	43.545	61.870
Mobile air conditioning for railway transport, kt $CO_{2\text{-eq}}$				0.013	0.028	0.095	0.184	0.280	0.304	0.422
One-component polyurethane foams (OPF), kt $CO_{2\text{-eq}}$						3.575	9.295	40.040	84.370	104.390
Panels and sandwich panels made of rigid polyurethane foams (RPUF), kt $CO_{2\text{-eq}}$						0.00389	0.00778	0.02048	0.03604	0.04914
Rigid polyurethane foam (PUF insulation by spraying, pouring, injection), kt $CO_{2\text{-eq}}$						0.1369	3.0398	4.7531	0.4368	6.0817
Extruded polystyrene foam (XPS), kt $CO_{2\text{-eq}}$						0.4032	0.8022	1.806	3.093	4.525
Fire protection, kt $CO_{2\text{-eq}}$						0.215	0.704	1.124	2.027	6.937
Aerosols use, kt $CO_{2\text{-eq}}$	6.431	12.507	13.288	11.461	9.350	13.661	16.517	21.940	30.588	41.709
Total HFCs emissions, kt $CO_{2\text{-eq}}$	6.431	13.019	14.142	15.746	29.041	64.269	105.224	187.313	285.171	402.410
Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Domestic refrigeration, kt $CO_{2\text{-eq}}$	43.286	23.947	15.735	15.849	14.196	15.103	15.876	14.671	5.863	6.093
Comercial refrigeration, kt $CO_{2\text{-eq}}$	64.360	67.802	68.124	70.364	73.209	76.950	78.296	76.069	75.825	131.686
Industrial refrigeration, kt $CO_{2\text{-eq}}$	122.819	146.503	158.043	147.479	75.862	59.237	46.653	34.302	26.132	21.252
Transport refrigeration, kt $CO_{2\text{-eq}}$	2.774	5.899	4.134	5.108	8.592	11.813	12.239	11.208	7.320	6.040
Comercial air conditioning, kt $CO_{2\text{-eq}}$	4.227	11.721	13.392	17.251	67.390	109.230	148.817	181.097	219.248	266.789
Industrial air conditioning, kt $CO_{2\text{-eq}}$				42.722	124.993	136.416	136.768	130.541	127.739	130.291
Mobile air conditioning for automotive vehicles, kt $CO_{2\text{-eq}}$	101.722	154.855	152.428	150.672	155.619	166.974	167.584	154.503	143.918	123.457
Mobile air conditioning for railway transport, kt $CO_{2\text{-eq}}$	0.471	0.723	0.642	0.679	0.716	0.677	0.500	0.460	0.432	0.434
One-component polyurethane foams (OPF), kt $CO_{2\text{-eq}}$	128.70	130.13	130.13	108.68	38.61	40.04	38.839	35.149	28.049	35.061
Panels and sandwich panels made of rigid polyurethane foams (RPUF), kt $CO_{2\text{-eq}}$	0.07351	0.10726	0.14187	0.18363	1.8007	2.0899	2.4313	2.232	1.836	2.246
Rigid polyurethane foam (PUF insulation by spraying, pouring, injection), kt $CO_{2\text{-eq}}$	14.186032	11.550922	7.775032	34.2449	44.1896	18.6981	28.2897	27.322	24.253	29.076
Extruded polystyrene foam (XPS), kt $CO_{2\text{-eq}}$	6.67095	8.88459	9.50235	9.867	12.5496	8.2892	8.0405	7.799	7.565	7.338
Fire protection, kt $CO_{2\text{-eq}}$	8.968	12.237	15.272	17.698	19.058	21.056	25.631	28.996	31.116	34.452
Aerosols use, kt $CO_{2\text{-eq}}$	62.958	73.121	88.620	123.288	183.618	174.764	171.885	144.054	76.298	94.783
Total HFCs emissions, kt $CO_{2\text{-eq}}$	561.216	647.482	663.940	744.085	820.404	841.338	881.849	848.404	775.595	888.999

Table A3.1.1.18 GHG emissions from use of sulfur hexafluoride

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
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
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
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
Leaks in production of the equipment,%	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
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
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
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
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
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
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
Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Amount of sulfur hexafluoride in the produced equipment, t	1.427	2.323	1.606	1.375	3.191	2.590	2.620	3.49	4.820	2.052	6.647	0.247	0.153	
Amount of sulfur hexafluoride in the installed equipment, t	1.01	0.50	0.69	2.09	3.03	2.36	1.65	0.238	0.177	0.124	0.168	0.165	0.167	
Amount of sulfur hexafluoride in the exploited equipment, t	8.67	13.91	18.66	23.51	37.90	46.76	52.37	69.386	90.872	107.479	139.398	169.242	210.242	
Leaks in production of the equipment,%	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	
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	
Emissions from production of the equipment, kt CO_2-eq	1.763	2.652	1.831	1.564	3.634	2.957	2.985	0.397	0.54948	0.2339	0.758	0.0281	0.0174	
Emissions from installation of the equipment, kt CO_2-eq	0.457	0.2289	0.314	0.953	1.383	1.077	0.753	0.108	0.0807	0.0565	0.0765	0.0752	0.0761	
Emissions from production and installation of the equipment, kt CO_2-eq	2.089	2.881	2.146	2.518	5.017	4.035	3.739	0.506	0.6032	0.2905	0.834	0.103	0.0935	
Emissions from exploitation of the equipment, kt CO_2-eq	0.988	1.586	2.127	2.679	4.320	5.330	5.970	7.91	10.3594	12.2526	15.891	19.293	24.017	
Total emissions, t CO_2-eq	3.0780	4.4671	4.2740	5.1982	9.3381	9.3656	9.7100	8.4141	10.9896	12.5431	16.726	19.369	24.111	

Table A3.1.1.19 Greenhouse gas emissions from Food and Beverages Industry

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Amount of meat and fish produced, kt	5419	4850	4079	3485	3089	2694	2558	2422	2286	2149	2013	1850	1941	1973
Amount of margarine produced, kt	917	743	552	485	360	405	252	202	210	282	365	461	463	551
Amount of mixed fodder produced, kt	1647	1454	1132	9730	7957	6439	4139	2226	2032	4635	3016	3348	4877	5191
Amount of bakery products produced, kt	6701	6685	6441	5444	4816	4114	3452	3060	2672	2510	2464	2450	2358	2427
Amount of confectionery products produced, kt	436	398	336	275	185	130	103	117	146	188	237	269	310	359
Amount of sugar produced, kt	6791	4786	3647	3993	3368	3894	3296	2034	1984	1858	1780	1947	1621	2486
Amount of cognac and brandy produced, 10^3 hl	110	105	82	75	57	58	90	96	79	2316	2592	2206	2378	3226
Amount of vodka produced, 10^3 hl	3090	3360	3670	4030	3630	3750	2480	2710	2160	211	312	284	448	485
Amount of wine produced, 10^3 hl	2720	2670	2200	1750	1690	1850	1400	1200	1070	856	948	1425	2081	2045
Amount of beer produced, 10^3 hl	138001	13100	11000	9090	9090	7100	6030	6130	6840	8407	10765	13059	15000	16994
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	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	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	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	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	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	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	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	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	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	0.000035	0.000035	0.000035
Total NMVOC emissions from food production, kt	110.943	88.680	73.666	80.329	68.021	68.880	56.023	39.200	36.828	38.163	36.395	39.277	37.220	47.433
Total NMVOC emissions from beverage production, kt	28.608	26.240	28.373	30.946	27.878	28.725	19.238	20.972	16.802	10.051	11.865	10.422	12.374	15.687
Total food and beverages, kt	139.551	114.919	102.039	111.274	95.899	97.605	75.261	60.171	53.629	48.214	48.260	49.699	49.595	63.120

Continuation of Table A3.1.1.19

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Amount of meat and fish produced, kt	1826	1863	1952	581	689	806	825	864.3	892.0	1048.8	1048.0	1303.5	1181.639
Amount of margarine produced, kt	397	422	415	417	401	428	443	435.0	417.0	377.6	385.4	313.5	291.151
Amount of mixed fodder produced, kt	3292	4178	4821	4953	5121	5881	6107	6244.1	6412.8	6839.0	7224.7	7047.3	7039.262
Amount of bakery products produced, kt	2307	2264	2160	2034	1978	1826	1807	1769.4	1732.1	1612.5	1574.5	1411.7	1332.983
Amount of confectionery products produced, kt	367	411	446	473	499	453	482	489.1	391.9	388.0	330.9	312.5	267.904
Amount of sugar produced, kt	2147	2139	2592	1867	1571	1275	1805	2586.4	2143.4	1263.4	2583.4	1766.8	2435.877
Amount of cognac and brandy produced, 10^3 hl	200	240	277	358	389	313	348	470.9	461.1	458.4	324.7	306.9	283.840
Amount of vodka produced, 10^3 hl	4029	3502	3549	3721	3996	4233	4247	3335.5	3384.0	2804.5	2154.2	1866.6	1663.681
Amount of wine produced, 10^3 hl	1541	2638	1056	2660	2953	3038	3715	1684.1	1275.7	1166.5	921.4	969.4	800.898
Amount of beer produced, 10^3 hl	19373	23805	26750	31579	32039	30005	30956	30555.4	29673.6	27397.5	25220.9	20514.1	18781.007
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	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	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	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	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	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	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	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	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	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	0.000035	0.000035
Total NMVOC emissions from food production, kt	40.028	40.946	45.643	37.593	34.448	31.823	37.448	45.168	40.471	31.208	44.644	34.91	40.930
Total NMVOC emissions from beverage production, kt	31.719	28.149	28.608	30.479	32.689	34.136	34.451	27.869	28.135	23.691	18.249	15.87	14.192
Total food and beverages, kt	71.747	69.095	74.250	68.072	67.137	65.959	71.899	73.037	68.606	54.898	62.893	50.78	55.123

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. State Statistic Service of Ukraine [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 2016 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	Measure-ment 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	17766.50	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. do-lomite 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 dolo-mite 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
Blast-furnace sinter production	kt	42991.6	43883.3	48134.0	48582.8	49002.8	51216.8	44553.1	35863.3
Specific standards for limestone use	kg/t	139.6	132.95	126.3	155.3	125.2	156.0	148.4	152.7
Specific standards for dolomite limestone use	kg/t	41.8	53.2	64.6	42.2	54.6	30.8	24.0	23.6
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
Dolomite limestone use	kt	1797.0	2334.6	3109.5	2050.2	2675.6	1577.5	1069.3	846.4
Dolomite use	kt	-	-	-	-	-	-	-	-
Iron ore pellets production	kt	13464.9	14968.4	16348.1	17062.9	18313	18835.2	20414.1	20435.0
Specific standards for limestone use	kg/t	49.0	49.03	49.03	49.03	49.03	49.03	59.26	49.03
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
Dolomite limestone use	kt	-	-	-	-	-	-	-	-
Iron production	kt	27633.3	29529.0	30977.6	30746.1	32929.3	35649.7	30991.3	25683.1
Specific standards for limestone use	kg/t	59.9	55	49	50	33	48	31	30
Specific standards for dolomite limestone use	kg/t	4.0	4	4	12	18	10	7	3
Limestone use	kt	1655.2	1609.3	1521.0	1537.3	1073.5	1707.6	954.5	765.4
Dolomite limestone use	kt	110.5	124.0	136.3	356.7	589.4	349.4	226.2	66.8
Steel production	kt	34546.4	37524.1	38718.5	38615.5	40891.8	42828.5	37082.3	29848.6
Specific standards for limestone use	kg/t	21.1	19.06	16.99	15.68	14.33	12.3	13.31	9.98
Specific standards for dolomite limestone use	kg/t	5.9	5.34	4.74	4.03	5.29	4.19	3.6	2.02
Specific standards for dolomite use	kg/t	11.02	10.88	10.73	10.77	8.26	8.79	7.48	6.33

Continuation of Table A3.1.2.1

Use of limestone	Measure-ment units	2002	2003	2004	2005	2006	2007	2008	2009
Limestone use	kt	719.4	703.9	657.8	605.5	586.0	526.8	497.9	297.9
Dolomite limestone use	kt	202.3	197.2	183.5	155.6	216.3	179.5	134.7	60.3
Limestone and dolomite limestone use	kt	921.7	901.1	841.4	761.1	802.3	706.2	632.6	358.2
Dolomite use	kt	375.3	401.8	415.4	415.9	337.8	376.5	279.8	188.9
Ferroalloys Production	kt	1288.3	1490.0	1912.3	1632.4	1709.6	1867.9	1662.8	1200.7
Specific standards for limestone use	kg/t	18.8	18.84	18.84	18.84	18.84	19.79	20.74	11.51
Limestone use	kt	24.3	28.1	36.0	30.8	32.2	37.0	34.5	13.8
Total limestone use	kt	9070.9	8920.8	9095.7	10555.1	8724.7	11184.7	9304.0	7555.3
Total dolomite limestone use	kt	2112.8	2659.0	3429.3	2562.5	3481.3	2106.3	1429.0	973.4
Total use of limestone, including dolomite limestone	kt	11183.7	11579.8	12525.0	13117.5	12206.0	13291.0	10733.0	8528.8
Total use of dolomite	kt	380.7	408.3	415.4	415.9	337.8	376.5	277.4	188.9
Total limestone and dolomite use	kt	11564.43	11988.1	12940.5	13533.4	12543.8	13667.4	11010.4	8717.7
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
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
CO_2 emissions from limestone use (incl. dolomite lime-stone)	kt	4848.9	5021.5	5432.5	5687.5	5294.5	5761.7	4652.3	3696.52
CO_2 emissions from dolomite use	kt	176.8	189.6	193.0	193.2	156.9	174.9	128.8	87.7661
Total CO_2 emission from limestone and dolomite use	kt	5025.7	5211.2	5625.5	5880.7	5451.4	5936.6	4781.1	3784.28
Total CO_2 emission factor	kg/t	0.4346	0.4347	0.4347	0.4345	0.4346	0.4344	0.4342	0.4341

Continuation of Table A3.1.2.1

Use of limestone	Measurement units	2010	2011	2012	2013	2014	2015	2016
Blast-furnace sinter production	kt	39492.6	40219.6	42598.0	43624	38294.601	33575.718	34383
Specific standards for limestone use	kg/t	131.7	132.8	119.42	122.296	118.111	101.079	112.531
Specific standards for dolomite limestone use	kg/t	23.2	31.5	33.195	33.994	26.517	48.064	59.791
Specific standards for dolomite use	kg/t	-	-	1.684	1.724	3.796	2.076	6.847
Limestone use	kt	5201.2	5341.2	5087.053	5335.1	4523.029	3393.809	3869.183
Dolomite limestone use	kt	916.2	1266.9	1414.041	1483	1015.478	1613.809	2055.791
Dolomite use	kt	-	-	71.735	75.2	145.4	69.707	235.417
Iron ore pellets production	kt	22141.0	22354.8	21959.6	23702	21915	21657	22386
Specific standards for limestone use	kg/t	38.8	34.7	27.954	30.172	27.897	27.5688	28.497
Specific standards for dolomite limestone use	kg/t	-	-	2.65	2.86	2.64	2.613483	2.701
Limestone use	kt	859.1	775.7	613.858	715.1	611.4	597.1	637.9
Dolomite limestone use	kt	-	-	58.193	67.8	57.96	56.60	60.47
Iron production	kt	27365.8	28877	28486.6	29088.7	24800.9	21862.8	23559.5
Specific standards for limestone use	kg/t	31	37.9	32.18	32.19	26.497	22.605	10.302
Specific standards for dolomite limestone use	kg/t	0.1	0.1	1.565	0.242	3.281	3.756	0.873
Limestone use	kt	859.3	1094.4	916.699	936.2	657.151	494.206	242.705
Dolomite limestone use	kt	2.7	2.9	44.582	7.0	81.379	82.121	20.571
Steel production	kt	32682	34762	32497.85	32673.02	27144.07	22997.614	24196
Specific standards for limestone use	kg/t	12.88	14.87	12.79	12.99	13.84	13.160	10.67
Specific standards for dolomite limestone use	kg/t	1.35	1.41	0.769	0.78	1.3	0.019	0.64
Specific standards for dolomite use	kg/t	4.04	4.12	2.014	2.05	1.65	0.013	0.63

Continuation of Table A3.1.2.1

Use of limestone	Measure-ment units	2010	2011	2012	2013	2014	2015	2016
Limestone use	kt	420.9	516.911	415.583	424.302	375.608	302.658	258.194
Dolomite limestone use	kt	44.1	49.014	24.991	25.515	35.200	0.448	15.568
Limestone and dolomite limestone use	kt	465.1	565.9	440.6	449.82	410.808	303.1063	273.762
Dolomite use	kt	132.0	143.2	65.5	66.82	44.701	0.300	15.139
Ferroalloys Production	kt	1671.3	1419.6	1279.084	1142.21	1362.473	1092.13	1188.35
Specific standards for limestone use	kg/t	23.3	52.44	64.636	60.48	55.18	55.410	13.323
Limestone use	kt	38.9	74.4	82.675	69.1	75.18	60.515	15.833
Total limestone use	kt	7379.4	7802.7	7115.9	7479.8	6242.3	4848.2	5023.8
Total dolomite limestone use	kt	963.1	1318.8	1541.8	1583.3	1190.0	1753.0	2152.4
Total use of limestone, including dolomite limestone	kt	8342.5	9121.5	8657.7	9063.1	7432.35	6601.22	7176.25
Total use of dolomite	kt	132.0	143.2	137.2	142.1	190.1	70.0	250.6
Total limestone and dolomite use	kt	8474.5	9264.7	8794.9	9205.2	7622.5	6671.2	7426.8
CO_2 emission factor at limestone use (incl. dolomite lime-stone)	kg/t	0.4334	0.4335	0.4335	0.4335	0.4335	0.4337	0.4338
CO_2 emission factor for dolomite use	kg/t	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645	0.4645
CO_2 emissions from limestone use (incl. dolomite lime-stone)	kt	3615.81	3954.0	3753.5	3929.2	3222.0	2863.1	3113.0
CO_2 emissions from dolomite use	kt	61.3319	66.5	63.7	66.0	88.3	32.5	116.4
Total CO_2 emission from limestone and dolomite use	kt	3677.14	4020.5	3817.2	3995.2	3310.3	2895.6	3229.4
Total CO_2 emission factor	kg/t	0.4339	0.4340	0.4340	0.4340	0.4343	0.4340	0.4348

A3.1.3 Method of CO_2 emission factor determination for coal 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 84.9 % (for dry coke), and of CO_2 emission factor at coke use calculated on basis of national data in 2016 amounted to 3.11 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 2016.

Table A3.1.4.1. The income side of the carbon balance in the blast furnace process in 2016

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	242.705	0.118	28.674
Dolomite limestone	Table P3.1.3.1	20.572	0.119	2.442
Blast-furnace coke use	Table P3.1.1.15	12872.717	0.849	10928.884
Coal	Table P3.1.1.15	108.792	0.796	86.621
Natural gas	Table P3.1.1.15	1.350	0.527	0.712
The total amount of carbon	The total of all components			11047.332

Table A3.1.4.2 The expense side of the carbon balance in the blast furnace process in 2016

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	242.705	0.118	28.674	-
Dolomite limestone use	Table P3.1.3.1	20.572	0.119	2.441	-
Coke use	Form 4-MTP	12872.717	0.849	10928.884	2.C.1.1
Carbon residue in pig iron	Table P3.1.3.1	23559.500	0.045	1049.135	2.C.1.1
Emissions from use of the technological component of coke	"Technological coke component" minus "Carbon residue in pig iron"			9879.749	2.C.1.1
Coal use	Table P3.1.3.1	108.79	0.796	86.621	2.C.1.1
Natural gas use	Table P3.1.3.1	1.350	0.527	0.711	2.C.1.1
The total amount of carbon	The total of all components			20927.081	
Carbon emissions from iron production	The total of all components accounted for in category 2.C.1.1			20927.081	2.C.1.1
CO_2 emissions from iron production	Table P3.1.3.1			36545.95	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 are conducted according to approved methodological recommendations [4, 21]. The collection of statistical observations at the regional and state levels is carried out according to the scheme, as shown in the Figure A3.2.1.1.1.

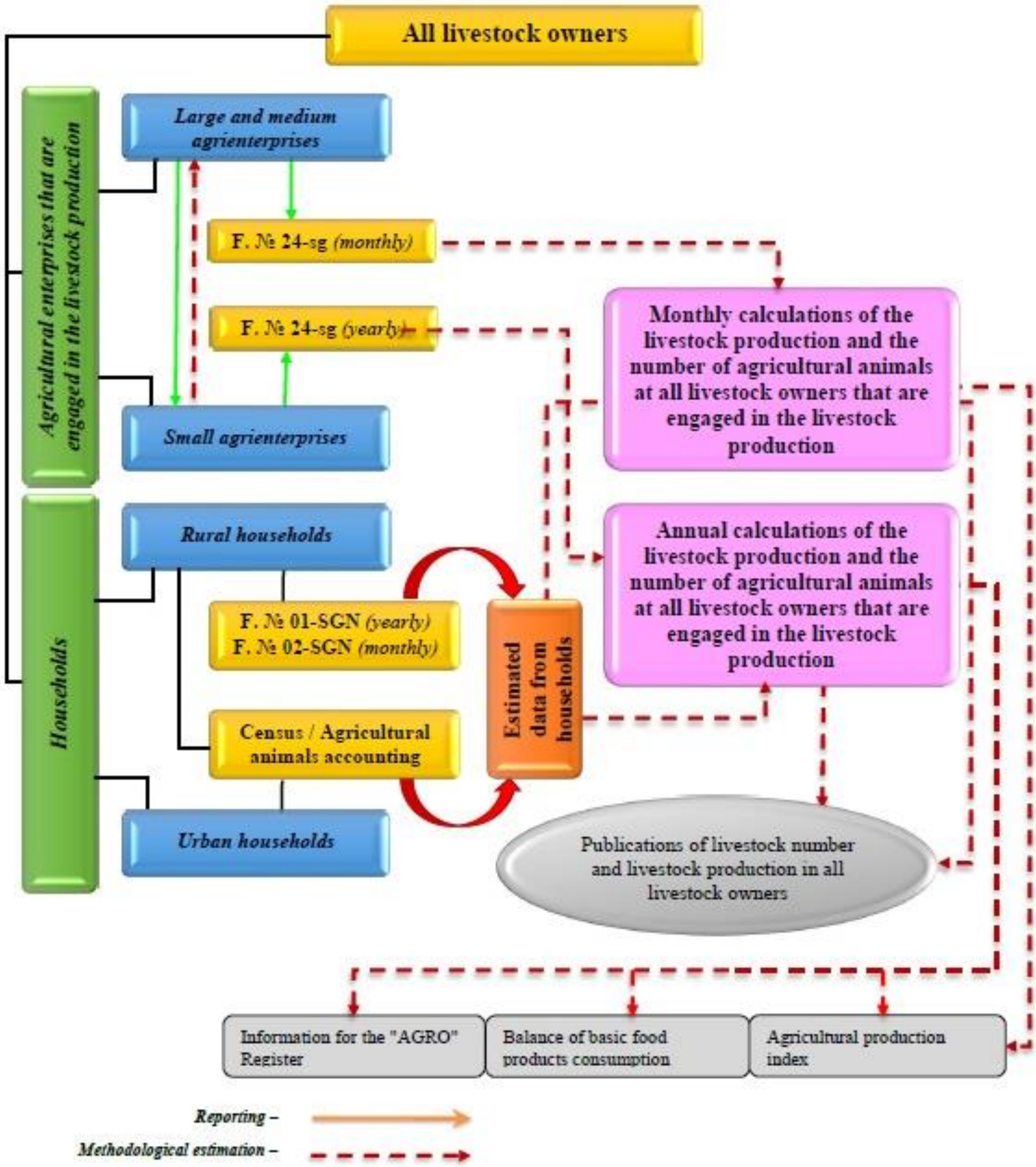

Figure A3.2.1.1.1. General scheme of statistical observations on the livestock production, the number of agricultural animals, their fodders provision and the interconnection with other statistical forms

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 are 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 were 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

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
Cattle			
Cows (without cows on fattening) - 40 (2): Dairy herd cows	40 (2) – 83-87	Dairy cows	Mature dairy cattle
Cows (without cows on fattening) - 40 (2): Dairy herd cows separated for group suckling rearing of calves	83		
Cows (without cows on fattening) - 40 (2): Beef cows	87	Beef cows	Other mature cattle
Heifers 2 years and older, bred	81	Heifers 2 years and older	
Heifers 2 years and older, not bred	82		
Beef and dairy cows on fattening*	-	Cows on fattening	
Bulls	84	Bulls	
Beef cattle (excluding cows)	86-87	Cattle on fattening (excluding cows)	Growing cattle
Cattle on fattening (excluding cows)*	-		
Heifers from 1 to 2 years, bred	80	Heifers from 1 to 2 years	
Calves under 1 year	77	Other cattle	
Draught oxen	85		
Cattle not included into the groups above (remainder)	-		
Swine			
Main sows	89	Main sows	Swine
Sows tested	90	Sows tested	
Repair swine older than 4 months	91	Repair swine older than 4 months	
Piglets up to 2 months	92	Piglets up to 2 months	
Fattening swine*	-	Fattening swine	
Not allocated as a separate group	-	Boars	
Not allocated as a separate group	-	Piglets 2 to 4 months	
Poultry			
Adult hens and roosters	110 (1)	Hens and roosters	Poultry
Young hens and roosters	110 (2)		
Adult geese	112 (1)	Geese	
Young geese	112 (2)		
Adult ducks	113 (1)	Ducks	
Young ducks	113 (2)		
Adult turkeys	114 (1)	Turkeys	
Young turkeys	114 (2)		
Other adult poultry	115 (1)	Other poultry	
Other young poultry	115 (2)		
Sheep			
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 cattle livestock.

Determination of average cattle livestock, according to information received from SSSU is carried out by using the approach [21], 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 and age groups for the reporting period were cattle accounting data ("Livestock accounting results", Table No.7), bulletin by the state statistical observation form No.24 (statistical bulletin "The status of livestock in Ukraine" [20]) and analytical study, which includes different approaches, particularly extrapolation, expert judgement 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 [21]. Results of estimation of the average annual cattle livestock at agrienterprises and in households in the areas of Polissia, Wooded Steppe, and Steppe are shown 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 [23], 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) and analytical study [2]. These sources specifies the total livestock of sheep, while the livestock of ewes and gimmers 1 year old and older is indicated as a separate group. The average annual population sheep for all categories of farms was determined in accordance to national methodology [21]. The livestock of rams and wethers was calculated on the basis 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 [15-16] assumed that the proportion of young sheep in fattening livestock is 83.5%, while of adult – 16.5%. The rest of sheep population was 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 [16], as well as statistical information on the population of sheep in all categories of farms by region were taken into account [19].

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) 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 in 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 were 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 [21]. The following groups are not indicated 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 was 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 were 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 [21].

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" and statistical yearbook "Animal production of Ukraine" [19-20] 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 age groups for GHG inventory was not applied due to lack of all the necessary data.

Total poultry population (without the breakdown into species) is determined on the basis of the sample data of the household survey in rural communities. First, the population of poultry per household is 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 [19].

The average annual population of sex-age groups of poultry at agricultural enterprises and in households was determined in accordance to national methodology [21].

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) were determined according to SSSU data ("Livestock accounting results", Table No.7; statistical bulletin "The status of livestock in Ukraine" [20], statistical yearbook "Animal Production of Ukraine" [19], 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 [21].

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 were 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 in 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 in 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	0.60	0.60	0.60	0.60	0.60	0.60	0.60
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 in 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 in 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 in 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	0.60	0.60	0.60	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 in 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
Cattle at agrienterprises	1 576.75	1 518.50	1 508.55	1 472.00	1 387.12	1 320.55	1 277.35
Cattle in households	3 083.80	2 941.60	3 027.30	3 117.95	2 907.87	2 677.39	2 632.33
Sheep	1 148.75	1 096.85	1 083.30	1 070.05	1 030.47	972.72	938.53
Swine at agrienterprises	3 466.55	3 472.20	3 438.05	3 717.90	3 873.48	3 860.36	3 781.91
Swine in households	4 301.95	4 194.60	4 036.90	4 031.55	3 878.73	3 595.39	3 340.94
Fur-bearing animals	304.60	366.20	420.35	379.35	334.75	297.65	273.92
Rabbits	5 487.65	5 498.70	5 650.10	5 696.45	5 603.49	5 429.63	5 355.37
Camels	0.80	0.80	0.80	0.80	0.80	0.81	0.83
Asses and mules	12.00	12.00	12.00	12.00	12.00	11.98	11.96
Buffaloes	0.08	0.06	0.06	0.06	0.06	0.06	0.06
Horses	428.80	404.95	386.15	365.40	337.69	315.81	303.30
Goats	633.35	638.70	655.50	666.65	648.47	628.72	636.85
Poultry at agrienterprises	105 457.65	108 143.30	111 806.95	124 980.55	131 406.80	125 752.61	119 544.96
Poultry in households	92 185.35	94 156.90	95 608.65	97 199.65	94 737.60	91 618.03	91 911.83

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

Cattle species	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

Cattle species	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										
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

Cattle species	2010	2011	2012	2013	2014	2015	2016
Mature dairy cattle at agrienterprises							
Polissia	157.30	152.90	150.90	149.10	139.75	127.25	119.85
Wooded Steppe	310.20	309.80	311.30	310.95	308.50	303.60	296.10
Steppe	129.35	123.70	117.25	110.25	103.31	96.72	91.88
Mature dairy cattle at households							
Polissia	770.05	745.25	734.55	724.10	688.55	644.10	618.80
Wooded Steppe	738.45	710.00	693.15	680.50	649.40	618.60	606.50
Steppe	578.50	565.05	561.10	556.65	538.10	513.06	499.69
Other mature cattle at *agrienterprises*							
Polissia	60.80	57.65	58.43	58.26	52.86	45.00	40.40
Wooded Steppe	89.11	83.58	82.92	82.14	79.31	74.23	67.58
Steppe	38.73	36.15	34.97	32.25	28.06	26.23	24.61
Other mature cattle at households							
Polissia	28.10	26.45	24.20	22.60	21.75	20.80	20.00
Wooded Steppe	24.55	22.55	20.85	20.20	19.05	17.45	17.40
Steppe	28.15	28.65	29.30	30.30	30.06	28.80	27.51
Growing cattle at agrienterprises							
Polissia	182.05	169.21	169.57	163.04	145.34	137.55	134.55
Wooded Steppe	433.45	422.88	429.38	421.17	397.54	388.57	385.32
Steppe	175.77	162.65	153.83	144.85	132.46	121.40	117.07
Growing cattle at households							
Polissia	275.35	245.25	273.15	304.60	265.75	220.80	221.21
Wooded Steppe	337.85	308.65	361.90	404.05	343.05	299.05	310.35
Steppe	302.80	289.75	329.10	374.95	352.17	314.73	310.86

A3.2.2 Enteric Fermentation

Table A3.2.2.1. The weighted average gross energy of 1 kg of fodder and the nutritional energy value coefficient for diets of different sex-age species of cattle by the ecological zones of Ukraine

Fodder type	Average GE, of 1 kg of fodder, MJ			Average energy nutritional value coefficient of fodder, fodder units in 1 kg		
	Polissia	Wooded Steppe	Steppe	Polissia	Wooded Steppe	Steppe
Dairy cows						
Concentrated fodders	17.16	14.48	16.85	1.09	0.99	1.18
Succulent fodders	3.29	3.22	4.11	0.17	0.16	0.22
Coarse fodders	15.37	14.74	14.95	0.44	0.44	0.60
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Heifers 2 years and older						
Concentrated fodders	17.13	14.55	16.54	1.09	0.99	1.14
Succulent fodders	3.32	3.24	4.30	0.17	0.16	0.23
Coarse fodders	15.19	14.73	14.98	0.45	0.44	0.59
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Heifers from 1 to 2 years						
Concentrated fodders	17.03	16.70	16.80	1.09	1.11	1.09
Succulent fodders	4.08	3.89	4.11	0.21	0.19	0.22
Coarse fodders	15.20	14.85	15.16	0.61	0.50	0.57
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Bulls						
Concentrated fodders	16.40	16.07	16.96	0.98	1.00	1.04
Succulent fodders	3.32	3.41	4.9	0.19	0.19	0.26
Coarse fodders	15.20	14.90	14.95	0.61	0.55	0.60
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Beef cows						
Concentrated fodders	17.03	16.83	16.98	1.09	1.08	1.22
Succulent fodders	4.00	4.40	4.90	0.20	0.21	0.26
Coarse fodders	15.08	14.81	15.05	0.45	0.42	0.48
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Cows on fattening						
Concentrated fodders	15.68	15.40	15.86	1.12	1.16	1.13
Succulent fodders	2.79	2.72	4.90	0.16	0.14	0.26

Fodder type	Average GE, of 1 kg of fodder, MJ			Average energy nutritional value coefficient of fodder, fodder units in 1 kg		
	Polissia	Wooded Steppe	Steppe	Polissia	Wooded Steppe	Steppe
Coarse fodders	15.50	14.80	15.30	0.40	0.46	0.41
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Other cattle and beef cattle fattening						
Concentrated fodders	16.04	16.03	16.17	1.09	1.14	1.16
Succulent fodders	3.62	3.92	4.90	0.19	0.19	0.26
Coarse fodders	15.29	14.80	15.20	0.54	0.46	0.49
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19
Other cattle						
Concentrated fodders	17.03	16.70	16.80	1.09	1.11	1.09
Succulent fodders	3.92	3.73	4.64	0.20	0.18	0.25
Coarse fodders	15.20	14.90	14.95	0.61	0.55	0.60
Other fodders	3.68	3.51	4.03	0.17	0.18	0.19

Table A3.2.2.2. Fodder consumption for cattle, kt

Fodder type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agricultural enterprises										
Dairy cows										
Concentrated fodders	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 fodders	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 fodders	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 fodders	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 fodders	826.55	756.74	641.44	657.03	664.50	536.25	399.72	255.58	232.06	216.34
Succulent fodders	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 fodders	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 fodders	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 fodders	254.91	238.47	198.26	190.12	190.21	159.86	120.04	73.62	67.00	64.80
Succulent fodders	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 fodders	442.39	478.26	508.81	447.92	444.18	434.16	384.21	300.77	247.59	218.37
Other fodders	1 254.32	1 049.78	964.84	813.41	674.78	657.71	581.22	493.81	402.84	351.57
Bulls										
Concentrated fodders	7.41	7.29	6.48	6.46	6.35	5.22	4.37	3.10	3.16	3.34
Succulent fodders	66.10	73.86	74.74	69.65	66.09	63.16	62.99	64.12	56.66	52.67
Coarse fodders	9.32	10.53	12.37	11.30	11.03	11.16	11.70	11.26	10.11	9.53
Other fodders	40.12	36.95	32.97	32.34	27.89	27.21	27.60	28.55	25.35	23.92
Beef cows										
Concentrated fodders	8.33	8.90	8.27	9.25	16.11	23.74	24.91	19.51	21.37	23.23
Succulent fodders	73.56	90.22	92.30	94.92	157.58	266.56	326.93	348.48	344.78	340.23
Coarse fodders	17.87	22.11	25.69	25.88	43.69	76.81	97.47	98.18	98.30	98.35
Other fodders	44.93	43.90	43.41	42.65	63.23	109.67	137.49	151.55	150.88	150.07
Cows on fattening										
Concentrated fodders	303.96	276.00	228.52	228.81	218.42	172.38	130.85	83.99	75.65	71.15
Succulent fodders	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 fodders	714.29	732.86	789.92	732.67	699.84	635.72	561.92	449.48	364.36	311.18
Other fodders	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 fattening										

Fodder type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Concentrated fodders	1 094.29	994.62	824.77	824.97	789.57	627.47	479.85	310.72	282.50	267.68
Succulent fodders	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 fodders	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 fodders	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 fodders	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 fodders	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 fodders	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 fodders	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
Households										
Dairy cows										
Concentrated fodders	509.51	544.47	640.70	671.15	727.87	785.73	841.72	825.51	844.03	857.96
Succulent fodders	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 fodders	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 fodders	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 fodders	21.35	23.21	27.34	28.64	29.68	28.29	27.52	29.34	31.85	34.45
Succulent fodders	398.84	437.22	520.20	559.81	542.66	489.70	452.39	460.59	451.30	436.96
Coarse fodders	66.13	72.70	84.51	88.92	86.72	84.61	84.30	87.15	98.70	111.20
Other fodders	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 fodders	48.17	52.33	63.55	69.21	74.06	67.90	59.79	58.83	60.52	64.22
Succulent fodders	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 fodders	130.23	143.54	173.19	190.03	191.24	179.16	160.65	153.10	164.76	182.40
Other fodders	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 fodders	0.62	0.68	0.95	1.22	1.40	1.53	1.45	1.43	1.66	1.80
Succulent fodders	15.87	17.46	23.13	29.69	33.27	34.76	31.79	31.15	32.82	32.10
Coarse fodders	3.42	3.60	4.58	5.98	6.87	7.21	6.61	6.39	7.72	8.69
Other fodders	15.59	17.12	21.31	28.12	32.76	33.56	30.06	29.91	36.91	42.42
Other cattle										
Concentrated fodders	590.12	511.41	282.24	277.09	271.19	233.19	226.65	236.82	232.31	233.64
Succulent fodders	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

Fodder type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Coarse fodders	1 501.65	1 309.19	733.39	717.44	653.08	578.07	578.62	589.34	605.15	634.95
Other fodders	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

Fodder type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agricultural enterprises										
Dairy cows										
Concentrated fodders	987.39	1 031.23	1 042.40	818.87	795.69	853.62	855.26	702.30	753.06	880.54
Succulent fodders	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 fodders	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 fodders	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 fodders	191.85	177.81	174.39	158.16	138.38	126.82	120.86	100.73	95.95	99.65
Succulent fodders	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 fodders	639.20	546.76	495.14	416.72	341.57	293.63	239.31	210.13	165.10	164.82
Other fodders	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 fodders	60.08	61.63	65.66	60.19	52.97	50.47	52.14	46.50	47.01	52.51
Succulent fodders	898.01	846.13	829.07	702.70	574.27	506.92	476.81	440.09	411.25	373.42
Coarse fodders	186.05	176.42	174.33	148.85	122.45	109.17	96.54	89.89	74.10	79.71
Other fodders	296.42	278.19	271.79	229.61	187.50	166.78	151.52	137.30	124.11	110.61
Bulls										
Concentrated fodders	3.36	3.18	3.20	2.90	2.53	2.56	2.74	2.20	1.91	2.10
Succulent fodders	47.06	40.11	36.27	29.83	23.77	21.97	22.58	18.95	14.26	12.46
Coarse fodders	8.59	7.38	6.77	5.64	4.54	4.21	3.98	3.53	2.49	2.50
Other fodders	21.63	18.63	17.12	14.31	11.55	11.22	10.37	9.14	7.27	5.91
Beef cows										
Concentrated fodders	25.15	27.12	29.05	31.06	33.96	36.83	38.18	32.70	31.34	33.60
Succulent fodders	336.75	333.90	329.09	323.12	320.63	313.88	313.51	294.46	247.70	204.30
Coarse fodders	98.56	98.86	98.89	99.06	101.30	102.99	95.18	89.11	71.65	68.79
Other fodders	149.43	148.89	148.02	148.56	153.93	159.74	156.96	143.11	134.39	118.05
Cows on fattening										
Concentrated fodders	61.67	54.40	53.08	46.89	39.42	36.87	37.13	31.86	30.02	30.91

Fodder type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Succulent fodders	1 054.60	869.89	781.82	640.50	504.94	438.13	401.49	358.39	314.27	264.59
Coarse fodders	246.96	201.10	181.54	149.17	117.49	103.17	89.47	80.31	62.09	61.19
Other fodders	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 fattening										
Concentrated fodders	235.41	210.95	207.24	186.45	162.49	156.25	158.63	136.17	128.93	133.13
Succulent fodders	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 fodders	828.92	687.93	627.25	525.94	428.80	385.68	337.77	304.97	238.02	234.18
Other fodders	1 183.18	987.43	890.38	742.86	610.21	551.70	502.78	443.17	386.91	324.43
Other cattle										
Concentrated fodders	264.12	309.74	347.80	226.47	231.94	283.45	308.32	244.77	231.24	286.18
Succulent fodders	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 fodders	762.87	825.86	862.97	524.81	503.28	575.96	534.72	440.78	336.10	406.65
Other fodders	1 311.25	1 396.16	1 455.32	881.83	822.79	910.80	866.45	686.72	559.26	554.98
Households										
Dairy cows										
Concentrated fodders	896.56	950.74	1 011.63	1 005.20	983.35	989.71	915.42	841.41	785.91	785.21
Succulent fodders	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 fodders	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 fodders	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 fodders	34.06	33.27	34.79	33.04	29.22	27.55	27.82	26.38	24.11	25.51
Succulent fodders	378.89	319.79	285.53	224.97	158.81	113.59	114.37	112.12	104.97	100.94
Coarse fodders	113.43	114.04	123.34	120.74	109.77	106.76	106.57	105.90	100.08	91.10
Other fodders	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 fodders	66.04	69.23	74.81	69.27	57.96	62.54	75.88	73.45	65.44	69.23
Succulent fodders	694.70	632.39	582.90	447.41	298.64	243.52	293.72	292.84	266.71	256.43
Coarse fodders	195.63	213.71	239.55	229.28	198.21	221.45	264.77	267.13	245.40	223.47
Other fodders	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 fodders	2.11	2.71	3.38	3.58	3.50	4.17	4.55	4.43	3.96	4.06
Succulent fodders	33.29	37.39	40.28	36.02	28.79	27.09	34.00	32.34	30.04	27.86
Coarse fodders	10.58	14.12	18.17	19.87	20.04	24.64	29.07	27.76	25.30	24.43

Fodder type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Other fodders	52.40	70.79	92.44	102.43	104.45	129.80	153.33	146.72	133.88	129.23
Other cattle										
Concentrated fodders	312.34	377.61	381.49	382.76	383.64	335.78	333.94	310.48	311.59	333.72
Succulent fodders	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 fodders	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 fodders	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

Fodder type	2010	2011	2012	2013	2014	2015	2016
Agricultural enterprises							
Dairy cows							
Concentrated fodders	864.52	867.98	1 029.48	1 053.38	1 102.99	1 173.84	1 132.27
Succulent fodders	6 573.00	6 551.51	6 592.05	6 539.08	6 152.22	5 898.54	6 008.30
Coarse fodders	1 169.11	1 137.41	1 202.20	1 240.07	1 338.22	1 314.19	1 296.65
Other fodders	1 557.93	1 556.65	1 350.37	1 151.75	1 032.32	955.10	800.44
Heifers 2 years and older							
Concentrated fodders	87.65	80.05	87.04	85.40	83.75	80.39	71.83
Succulent fodders	715.12	683.05	651.53	650.02	581.52	521.17	501.82
Coarse fodders	148.75	136.49	133.12	132.16	137.86	127.58	112.70
Other fodders	188.65	181.44	170.90	164.64	135.68	117.57	86.51
Heifers from 1 to 2 years							
Concentrated fodders	50.12	49.78	58.86	60.27	62.50	63.92	90.92
Succulent fodders	389.66	404.01	423.05	439.13	410.54	393.88	608.63
Coarse fodders	78.14	76.99	82.44	85.32	93.73	92.97	131.17
Other fodders	108.89	109.99	112.00	114.02	99.08	94.88	113.93
Bulls							
Concentrated fodders	1.96	1.82	1.97	1.64	1.48	1.40	1.22
Succulent fodders	12.00	11.22	10.19	8.23	6.72	5.74	5.44
Coarse fodders	2.29	2.07	2.01	1.69	1.59	1.40	1.22
Other fodders	5.33	5.08	3.96	3.01	2.48	2.05	1.39
Beef cows							
Concentrated fodders	29.94	26.49	30.09	29.39	25.40	22.21	20.23
Succulent fodders	203.30	196.29	183.63	174.24	147.69	117.60	115.69

Fodder type	2010	2011	2012	2013	2014	2015	2016
Coarse fodders	61.16	56.41	54.71	54.53	52.92	45.07	39.82
Other fodders	101.82	103.18	103.29	94.35	74.43	59.40	35.80
Cows on fattening							
Concentrated fodders	27.87	26.23	28.49	27.67	27.12	26.88	25.69
Succulent fodders	262.74	260.12	249.62	246.32	220.48	205.19	212.97
Coarse fodders	56.47	53.09	51.72	50.74	52.72	50.39	47.48
Other fodders	65.86	64.70	61.13	58.29	47.76	43.33	33.83
Other cattle and beef cattle fattening							
Concentrated fodders	119.52	111.91	123.45	120.00	114.59	113.13	109.04
Succulent fodders	916.29	904.63	870.53	854.35	750.63	691.69	721.87
Coarse fodders	215.05	202.81	199.50	196.24	200.41	191.43	181.88
Other fodders	296.60	293.80	284.41	268.16	214.54	193.17	147.66
Other cattle							
Concentrated fodders	249.06	216.80	248.52	247.47	240.32	240.20	218.67
Succulent fodders	1 946.84	1 760.38	1 815.35	1 818.27	1 591.19	1 488.75	1 492.78
Coarse fodders	368.88	314.70	328.09	329.87	336.12	326.07	291.45
Other fodders	553.06	457.93	451.91	452.68	351.42	335.35	253.43
Households							
Dairy cows							
Concentrated fodders	757.44	755.92	738.49	719.93	688.27	651.39	632.90
Succulent fodders	6 456.72	6 116.02	6 027.58	6 168.97	5 937.59	5 575.39	5 415.61
Coarse fodders	5 879.95	5 691.47	5 587.96	5 604.26	5 377.77	5 064.17	4 918.27
Other fodders	25 884.35	25 069.55	24 628.22	24 709.96	23 727.20	22 352.71	21 710.73
Heifers 2 years and older							
Concentrated fodders	25.03	25.43	24.27	23.28	23.11	22.14	21.49
Succulent fodders	97.59	94.83	89.89	88.50	87.42	83.52	81.21
Coarse fodders	87.56	82.91	78.20	78.42	77.57	74.13	72.04
Other fodders	529.63	516.33	489.08	482.14	478.91	458.61	444.86
Heifers from 1 to 2 years							
Concentrated fodders	65.22	62.94	67.28	69.01	61.63	54.86	53.46
Succulent fodders	238.51	220.56	234.38	246.96	219.83	195.54	190.84
Coarse fodders	206.72	186.50	197.48	212.01	188.97	168.37	164.31
Other fodders	1 418.61	1 312.12	1 393.22	1 468.14	1 308.40	1 163.63	1 134.79

Fodder type	2010	2011	2012	2013	2014	2015	2016
Bulls							
Concentrated fodders	3.65	3.34	3.36	3.16	2.63	2.30	2.21
Succulent fodders	24.89	21.52	21.88	21.56	17.99	15.57	14.99
Coarse fodders	21.94	19.47	19.73	19.09	15.97	13.91	13.36
Other fodders	115.99	102.78	104.04	100.62	84.12	73.18	70.29
Other cattle							
Concentrated fodders	301.79	308.60	364.12	399.75	354.59	306.92	311.52
Succulent fodders	1 083.87	1 059.99	1 243.43	1 401.23	1 235.37	1 066.71	1 085.73
Coarse fodders	913.65	873.20	1 019.82	1 171.74	1 037.91	898.67	913.08
Other fodders	6 563.92	6 433.42	7 540.49	8 504.75	7 528.49	6 509.89	6 613.09

Table A3.2.2.3. Cattle fodder consumption structure, rel. u

Fodder type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cows (including bulls) at agrienterprises										
Concentrated fodders	0.23	0.22	0.19	0.20	0.21	0.18	0.16	0.12	0.13	0.15
Succulent fodders	0.44	0.47	0.48	0.48	0.47	0.48	0.49	0.52	0.51	0.50
Coarse fodders	0.16	0.17	0.21	0.20	0.21	0.22	0.23	0.23	0.23	0.23
Other fodders	0.17	0.14	0.12	0.12	0.11	0.11	0.12	0.13	0.13	0.13
Other cattle (without cows and bulls) at agricultural enterprises										
Concentrated fodders	0.23	0.21	0.19	0.20	0.21	0.19	0.16	0.13	0.14	0.15
Succulent fodders	0.40	0.43	0.43	0.43	0.43	0.43	0.44	0.47	0.46	0.45
Coarse fodders	0.20	0.21	0.24	0.24	0.25	0.26	0.26	0.26	0.26	0.26
Other fodders	0.18	0.15	0.14	0.14	0.12	0.12	0.13	0.14	0.14	0.14
Cows (including bulls) in households										
Concentrated fodders	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08
Succulent fodders	0.37	0.38	0.39	0.38	0.38	0.38	0.38	0.38	0.35	0.31
Coarse fodders	0.23	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.24
Other fodders	0.32	0.33	0.32	0.32	0.32	0.32	0.32	0.32	0.34	0.36
Other cattle (without cows and bulls) in households										
Concentrated fodders	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.13
Succulent fodders	0.37	0.36	0.37	0.37	0.36	0.35	0.34	0.35	0.32	0.29
Coarse fodders	0.15	0.15	0.15	0.15	0.15	0.16	0.17	0.17	0.18	0.19
Other fodders	0.36	0.38	0.37	0.38	0.38	0.37	0.37	0.35	0.37	0.39

Fodder type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cows (including bulls) at agrienterprises										
Concentrated fodders	0.16	0.17	0.19	0.20	0.22	0.23	0.25	0.24	0.27	0.31
Succulent fodders	0.49	0.48	0.47	0.46	0.45	0.43	0.44	0.43	0.43	0.40
Coarse fodders	0.22	0.22	0.22	0.21	0.21	0.21	0.20	0.20	0.18	0.19
Other fodders	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.13	0.12	0.10
Other cattle (without cows and bulls) at agricultural enterprises										
Concentrated fodders	0.17	0.18	0.19	0.20	0.21	0.23	0.25	0.24	0.26	0.29
Succulent fodders	0.45	0.44	0.43	0.42	0.42	0.41	0.41	0.41	0.42	0.38
Coarse fodders	0.25	0.25	0.25	0.25	0.24	0.24	0.23	0.23	0.21	0.22
Other fodders	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.10
Cows (including bulls) in households										
Concentrated fodders	0.08	0.08	0.08	0.09	0.09	0.09	0.08	0.08	0.08	0.09

Fodder type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Succulent fodders	0.28	0.25	0.22	0.19	0.15	0.12	0.13	0.13	0.13	0.12
Coarse fodders	0.25	0.26	0.27	0.28	0.29	0.30	0.30	0.30	0.30	0.30
Other fodders	0.38	0.41	0.43	0.45	0.47	0.49	0.49	0.49	0.49	0.49
Other cattle (without cows and bulls) in households										
Concentrated fodders	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.14
Succulent fodders	0.26	0.23	0.19	0.16	0.13	0.10	0.10	0.10	0.10	0.10
Coarse fodders	0.20	0.21	0.22	0.23	0.24	0.24	0.24	0.25	0.25	0.24
Other fodders	0.41	0.43	0.45	0.48	0.50	0.52	0.52	0.52	0.52	0.52

Fodder type	2010	2011	2012	2013	2014	2015	2016
Cows (including bulls) at agrienterprises							
Concentrated fodders	0.31	0.32	0.36	0.36	0.38	0.40	0.40
Succulent fodders	0.40	0.40	0.38	0.38	0.35	0.34	0.35
Coarse fodders	0.19	0.19	0.19	0.19	0.21	0.20	0.20
Other fodders	0.10	0.10	0.08	0.07	0.06	0.06	0.05
Other cattle (without cows and bulls) at agricultural enterprises							
Concentrated fodders	0.28	0.28	0.30	0.30	0.31	0.33	0.32
Succulent fodders	0.40	0.41	0.39	0.39	0.37	0.36	0.39
Coarse fodders	0.22	0.21	0.21	0.21	0.23	0.23	0.23
Other fodders	0.11	0.11	0.10	0.10	0.08	0.08	0.06
Cows (including bulls) in households							
Concentrated fodders	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Succulent fodders	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Coarse fodders	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Other fodders	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Other cattle (without cows and bulls) in households							
Concentrated fodders	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Succulent fodders	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Coarse fodders	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Other fodders	0.52	0.52	0.52	0.52	0.52	0.52	0.52

Table A3.2.2.4. 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 A3.2.2.5. The cattle species composition and the average live weight of beef cattle in Ukraine

Breed	The species composition, %	Average live weight, kg	
		Beef cows	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 A3.2.2.6. Source data for sheep gross energy estimation

Sex-age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Average live weight, kg										
Ewes and gimmers 1 year and older	56.70	56.70	56.70	56.70	56.70	56.70	56.70	56.70	56.70	56.70
Rams	109.30	109.30	109.30	109.30	109.30	109.00	109.00	109.00	109.00	109.00
Fattening livestock	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Wethers	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Lambs up to 4 months and 4-12 months repair young sheep	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

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Average live weight, kg										
Ewes and gimmers 1 year and older	57.10	57.10	57.10	55.90	56.00	56.10	56.10	56.20	56.20	56.20
Rams	107.70	107.70	107.70	104.40	104.60	104.70	104.70	104.90	104.90	104.90
Fattening livestock	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Wethers	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Lambs up to 4 months and 4-12 months repair young sheep	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

Sex-age group	2010	2011	2012	2013	2014	2015	2016
Average live weight, kg							
Ewes and gimmers 1 year and older	56.40	57.00	57.01	57.01	57.01	57.01	57.01
Rams	105.10	105.80	105.85	105.85	105.85	105.85	105.85
Fattening livestock	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Wethers	42.50	42.50	42.50	42.50	42.50	42.50	42.50
Lambs up to 4 months and 4-12 months repair young sheep	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)	117.0	147.0	145.0	145.0	139.1	136.8	130.4
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
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

Table A3.2.2.7. 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 A3.2.2.8. The species composition of sheep in Ukraine, rel. u

Breeds	1990	1995	2000	2005	2010	2015	2016
Tsigai and breed types	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
Askanian fine-wool and the breed type	0.39	0.37	0.18	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
Karakul	0.03	0.03	0.02	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
Sokolska	0.009	0.009	0.01	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
Polvars	0.00004	0.0001	0.0003	0.0004	0.0003	0.0003	0.0003
Romanovska	0.00008	0.0004	0.001	0.003	0.010	0.010	0.010
Latvian dark face	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008
Romney Marsh	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008
Charolais	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008
Olibs	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008
Ostfriesische	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008
Texel	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008
North Caucasian	0.0001	0.0002	0.0006	0.0008	0.0008	0.0008	0.0008

Table A3.2.2.9. 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 is indicated, because repair rams are used only at breeding farms, and their share is insignificant.

Table A3.2.2.10. 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 and 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 and age group	2010	2011	2012	2013	2014	2015	2016
Mature dairy cattle	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
Growing cattle	266.98	267.19	267.87	268.41	268.77	268.67	272.87

Table A3.2.2.11. 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	265.7	263.3	240.3	236.7	231.0	217.0	206.8	195.0	215.3	190.4
Heifers 2 years and older	154.7	156.1	159.3	158.5	158.9	160.5	162.4	164.0	163.5	162.9
Heifers from 1 to 2 years	125.6	126.5	128.5	127.9	128.0	129.2	130.3	131.4	131.1	130.6
Bulls	166.5	167.0	168.9	168.4	168.4	169.9	171.3	172.3	171.9	171.5
Beef cows	187.0	189.3	193.3	192.0	192.0	194.8	197.7	199.7	199.2	198.5
Cows on fattening	208.9	211.1	217.2	216.0	216.8	219.2	221.5	222.6	221.3	220.1
Other cattle and beef cattle fattening	101.7	102.6	104.9	104.4	104.7	105.8	106.9	107.7	107.2	106.8
Other cattle	87.9	85.7	84.8	82.1	77.1	68.4	67.2	59.9	78.7	58.2
Households										
Cows	221.0	237.2	240.2	242.8	240.2	236.9	240.5	235.6	236.5	237.2
Heifers 2 years and older	159.3	159.1	158.7	158.3	157.8	158.4	159.1	159.3	160.1	161.0
Heifers from 1 to 2 years	128.2	128.2	128.1	128.0	127.8	128.0	128.3	128.2	128.6	129.1
Bulls	175.1	174.6	174.1	174.4	174.6	174.5	174.3	174.1	175.2	176.3
Other cattle	297.8	288.6	182.4	198.0	202.0	201.4	215.3	217.2	202.8	188.9

Sex-age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agrienterprises										
Cows	178.2	208.7	222.6	199.2	220.0	248.9	253.2	247.6	253.1	274.2
Heifers 2 years and older	162.5	162.3	161.6	161.0	160.7	160.2	158.1	158.8	156.2	156.5
Heifers from 1 to 2 years	130.3	130.1	129.6	129.2	128.9	128.4	127.0	127.4	125.6	125.5
Bulls	171.1	170.7	170.3	169.9	169.4	168.8	167.5	168.5	166.9	166.5
Beef cows	198.1	197.8	197.2	196.6	196.3	195.7	193.2	194.6	191.7	191.1
Cows on fattening	218.8	217.4	216.3	215.2	214.1	213.2	209.8	210.7	205.7	206.2
Other cattle and beef cattle fattening	106.4	106.0	105.5	105.1	104.7	104.2	102.8	103.3	101.4	101.3
Other cattle	48.7	65.6	73.4	54.2	71.0	94.6	97.3	90.5	94.8	120.7
Households										
Cows	239.0	240.0	245.4	244.3	250.1	267.8	288.4	278.2	285.6	284.9
Heifers 2 years and older	161.3	161.6	162.4	163.0	163.5	164.4	164.8	165.6	166.2	164.7
Heifers from 1 to 2 years	129.6	130.1	130.6	131.0	131.5	132.1	132.1	132.3	132.5	131.6
Bulls	177.4	178.6	179.6	180.6	181.7	182.7	183.2	183.0	183.1	182.7
Other cattle	191.7	171.9	153.0	159.8	180.3	168.9	169.0	170.9	187.0	186.9

Sex-age group	2010	2011	2012	2013	2014	2015	2016
Agrienterprises							
Cows	272.2	274.4	291.0	295.4	307.4	318.9	325.1
Heifers 2 years and older	156.7	156.6	155.5	155.8	157.4	157.1	156.7
Heifers from 1 to 2 years	125.7	125.6	124.8	125.0	125.7	125.5	125.3
Bulls	166.2	165.9	164.9	165.1	165.8	165.2	164.8
Beef cows	190.6	190.9	188.8	189.6	192.7	192.9	192.4
Cows on fattening	206.1	205.6	203.4	203.6	206.0	205.3	204.4
Other cattle and beef cattle fattening	101.5	101.5	100.5	100.6	101.6	101.3	101.1
Other cattle	123.0	114.7	124.0	130.5	132.7	133.1	143.8
Households							
Cows	287.0	286.6	286.1	291.5	292.7	291.2	291.1
Heifers 2 years and older	164.3	163.3	163.2	163.6	163.3	163.1	163.2
Heifers from 1 to 2 years	131.5	131.0	131.0	131.3	131.2	131.2	131.3
Bulls	182.7	182.6	182.6	182.8	182.8	182.8	182.8
Other cattle	186.4	198.3	198.9	196.6	196.9	197.6	196.8

A3.2.3 Manure Management

Table A3.2.3.1. Excretion norms, ash content, and maximum methane-producing capacity of the manure

Animal species	Manure excretion in the dry matter (DM), 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	0.8992	0.15	0.45
Sows tested	0.8030	0.15	0.45
Repair swine 4 months and older	0.2409	0.15	0.45
Piglets up to 2 months	0.0399	0.15	0.45
Piglets 2 to 4 months	0.2409	0.15	0.45
Fattening swine	0.6509	0.15	0.45
Boars	1.1672	0.15	0.45

Animal species	Manure excretion in the dry matter (DM), 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
Swine in households			
Main sows	1.1690	0.15	0.45
Repair swine 4 months and older	0.3132	0.15	0.45
Piglets up to 2 months	0.0519	0.15	0.45
Piglets 2 to 4 months	0.3132	0.15	0.45
Fattening swine	0.8461	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. Cattle average digestibility of the feed (DE), %

Cattle species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agricultural enterprises										
Dairy cows	68.7	68.3	67.8	67.9	67.7	67.7	67.6	67.6	67.7	67.7
Heifers 2 years and older	65.2	64.9	64.6	64.6	64.4	64.3	64.2	64.3	64.3	64.3
Heifers from 1 to 2 years	66.9	66.8	66.5	66.5	66.4	66.4	66.3	66.3	66.3	66.4
Bulls	70.6	70.3	69.8	69.9	69.8	69.6	69.4	69.5	69.5	69.5
Beef cows	65.5	64.8	64.4	64.4	64.1	64.0	64.0	64.2	64.2	64.2
Cows on fattening	66.7	66.3	65.9	65.8	65.5	65.4	65.4	65.6	65.6	65.6
Other cattle and beef cattle fattening	67.0	66.6	66.1	66.1	65.8	65.7	65.7	65.8	65.9	65.9
Other cattle	66.9	66.8	66.5	66.5	66.4	66.4	66.3	66.4	66.4	66.4
Households										
Dairy cows	67.8	67.8	67.8	67.9	67.9	67.8	67.8	67.9	67.9	68.0
Heifers 2 years and older	67.8	67.9	67.8	67.9	67.9	67.9	67.8	67.7	67.7	67.8
Heifers from 1 to 2 years	66.4	66.5	66.4	66.5	66.6	66.5	66.5	66.3	66.5	66.6
Bulls	69.2	69.3	69.2	69.3	69.3	69.3	69.2	69.3	69.3	69.4
Other cattle	66.4	66.5	66.5	66.5	66.6	66.5	66.5	66.3	66.5	66.6

Cattle species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agricultural enterprises										
Dairy cows	67.7	67.8	67.8	67.8	67.8	67.9	67.9	67.9	68.1	67.9
Heifers 2 years and older	64.3	64.3	64.4	64.4	64.4	64.4	64.5	64.5	64.7	64.5
Heifers from 1 to 2 years	66.4	66.4	66.4	66.4	66.4	66.5	66.6	66.6	66.8	66.6
Bulls	69.5	69.6	69.6	69.6	69.7	69.8	69.8	69.8	70.0	69.8
Beef cows	64.1	64.1	64.1	64.1	64.2	64.2	64.4	64.3	64.7	64.5
Cows on fattening	65.7	65.7	65.7	65.7	65.8	65.8	65.9	65.9	66.2	65.9
Other cattle and beef cattle fattening	65.9	65.9	65.9	65.9	66.0	66.0	66.2	66.1	66.4	66.1
Other cattle	66.4	66.5	66.5	66.5	66.5	66.6	66.7	66.7	66.9	66.7
Households										
Dairy cows	68.1	68.2	68.3	68.4	68.5	68.6	68.5	68.5	68.5	68.6
Heifers 2 years and older	67.8	67.9	67.9	67.9	68.0	68.0	68.0	68.0	68.0	68.1
Heifers from 1 to 2 years	66.7	66.8	67.0	67.1	67.2	67.3	67.3	67.3	67.3	67.4
Bulls	69.5	69.5	69.6	69.7	69.7	69.8	69.8	69.8	69.8	69.8
Other cattle	66.8	66.9	67.0	67.1	67.3	67.4	67.4	67.4	67.4	67.5

Cattle species	2010	2011	2012	2013	2014	2015	2016
Agricultural enterprises							
Dairy cows	67.9	67.9	67.8	67.7	67.5	67.5	67.4
Heifers 2 years and older	64.6	64.6	64.6	64.6	64.3	64.2	64.2
Heifers from 1 to 2 years	66.7	66.7	66.8	66.8	66.5	66.5	66.6
Bulls	69.8	69.9	69.7	69.6	69.3	69.3	69.1
Beef cows	64.4	64.7	64.8	64.5	64.0	63.8	62.9
Cows on fattening	65.9	66.0	66.0	65.9	65.5	65.5	65.4
Other cattle and beef cattle fattening	66.1	66.2	66.3	66.2	65.7	65.7	65.5
Other cattle	66.8	66.8	66.9	66.9	66.6	66.6	66.7
Households							
Dairy cows	68.6	68.6	68.6	68.6	68.6	68.6	68.6
Heifers 2 years and older	68.1	68.1	68.1	68.1	68.1	68.1	68.1
Heifers from 1 to 2 years	67.4	67.5	67.5	67.4	67.4	67.4	67.4
Bulls	69.8	69.8	69.8	69.8	69.8	69.8	69.8
Other cattle	67.5	67.5	67.5	67.5	67.5	67.5	67.5

Table A3.2.3.3. Daily volatile solids (VS), kg dry matter animal^{-1} day^{-1}

Cattle species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agricultural enterprises										
Dairy cows	4.27	4.28	3.96	3.89	3.82	3.59	3.43	3.23	3.56	3.15
Heifers 2 years and older	2.73	2.78	2.86	2.85	2.87	2.90	2.94	2.96	2.95	2.94
Heifers from 1 to 2 years	2.12	2.14	2.19	2.18	2.19	2.21	2.24	2.25	2.25	2.24
Bulls	2.53	2.56	2.63	2.61	2.62	2.66	2.70	2.71	2.70	2.69
Beef cows	3.28	3.37	3.48	3.46	3.49	3.55	3.60	3.62	3.61	3.60
Cows on fattening	3.55	3.63	3.77	3.75	3.80	3.85	3.89	3.89	3.87	3.84
Other cattle and beef cattle fattening	1.71	1.75	1.81	1.80	1.82	1.85	1.87	1.87	1.86	1.85
Other cattle	1.48	1.45	1.45	1.40	1.32	1.17	1.15	1.03	1.35	1.00
Cattle at households										
Dairy cows	3.69	3.95	4.01	4.04	4.00	3.95	4.01	3.92	3.93	3.93
Heifers 2 years and older	2.66	2.65	2.65	2.63	2.62	2.64	2.65	2.66	2.67	2.69
Heifers from 1 to 2 years	2.22	2.22	2.22	2.21	2.20	2.21	2.22	2.22	2.23	2.23
Bulls	2.80	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.80	2.81
Other cattle	5.16	4.98	3.15	3.42	3.48	3.48	3.72	3.77	3.51	3.25
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	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Sows tested	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Repair swine 4 months and older	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Piglets up to 2 months	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
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	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Boars	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Swine at households										

Cattle species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Main sows	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Repair swine 4 months and older	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Piglets up to 2 months	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
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	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
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

Cattle species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agricultural enterprises										
Dairy cows	2.94	3.44	3.67	3.28	3.62	4.09	4.16	4.07	4.14	4.51
Heifers 2 years and older	2.93	2.93	2.92	2.90	2.90	2.89	2.84	2.86	2.79	2.81
Heifers from 1 to 2 years	2.23	2.23	2.22	2.21	2.20	2.19	2.16	2.17	2.13	2.14
Bulls	2.68	2.67	2.67	2.66	2.65	2.63	2.61	2.63	2.58	2.59
Beef cows	3.59	3.59	3.58	3.57	3.56	3.54	3.48	3.52	3.43	3.43
Cows on fattening	3.82	3.79	3.77	3.75	3.73	3.71	3.64	3.66	3.54	3.58
Other cattle and beef cattle fattening	1.85	1.84	1.83	1.82	1.81	1.80	1.77	1.78	1.74	1.75
Other cattle	0.83	1.12	1.25	0.93	1.21	1.61	1.65	1.54	1.60	2.05
Cattle at households										
Dairy cows	3.95	3.96	4.04	4.01	4.09	4.37	4.71	4.54	4.67	4.65
Heifers 2 years and older	2.69	2.69	2.70	2.71	2.71	2.72	2.73	2.75	2.76	2.73
Heifers from 1 to 2 years	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.24	2.24	2.22
Bulls	2.82	2.84	2.85	2.86	2.87	2.88	2.89	2.89	2.89	2.88
Other cattle	3.29	2.94	2.61	2.71	3.05	2.85	2.85	2.88	3.15	3.14
Sheep at all categories of farms										
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

Cattle species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Sows tested	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Repair swine 4 months and older	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Piglets up to 2 months	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
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	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
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	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Repair swine 4 months and older	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Piglets up to 2 months	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
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	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
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

Cattle species	2010	2011	2012	2013	2014	2015	2016
Cattle at agricultural enterprises							
Dairy cows	4.48	4.51	4.79	4.89	5.11	5.30	5.42
Heifers 2 years and older	2.81	2.81	2.79	2.79	2.85	2.84	2.84
Heifers from 1 to 2 years	2.14	2.13	2.12	2.12	2.15	2.14	2.14
Bulls	2.59	2.58	2.57	2.59	2.62	2.61	2.61

Cattle species	2010	2011	2012	2013	2014	2015	2016
Beef cows	3.43	3.42	3.37	3.41	3.51	3.53	3.60
Cows on fattening	3.58	3.56	3.52	3.53	3.61	3.60	3.59
Other cattle and beef cattle fattening	1.75	1.74	1.73	1.73	1.77	1.77	1.77
Other cattle	2.08	1.94	2.10	2.21	2.26	2.26	2.44
Cattle at households							
Dairy cows	4.68	4.68	4.67	4.76	4.78	4.75	4.75
Heifers 2 years and older	2.72	2.70	2.70	2.70	2.70	2.70	2.70
Heifers from 1 to 2 years	2.22	2.21	2.20	2.21	2.21	2.21	2.21
Bulls	2.88	2.88	2.88	2.88	2.88	2.88	2.88
Other cattle	3.14	3.33	3.34	3.31	3.31	3.32	3.31
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
Rams	0.55	0.56	0.56	0.56	0.56	0.56	0.56
Wethers	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
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
Swine at agricultural enterprises							
Main sows	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Sows tested	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Repair swine 4 months and older	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Piglets up to 2 months	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Piglets 2 to 4 months	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fattening swine	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Boars	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Swine at households							
Main sows	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Repair swine 4 months and older	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Piglets up to 2 months	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Piglets 2 to 4 months	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Fattening swine	0.72	0.72	0.72	0.72	0.72	0.72	0.72

Cattle species	2010	2011	2012	2013	2014	2015	2016
Boars	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
Geese	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
Turkeys	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

Table A3.2.3.4. 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
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	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
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										
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										

MMS types	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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
Cattle at agrienterprises							
Liquid slurry	0.044	0.040	0.042	0.045	0.047	0.049	0.052
Solid storage	0.476	0.477	0.473	0.471	0.466	0.463	0.459
Pasture/Range/Paddock	0.478	0.480	0.479	0.478	0.476	0.475	0.474
Composting	0.002	0.003	0.006	0.007	0.010	0.013	0.015
Cattle in households							
Solid storage	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
Sheep at all categories of farms							
Solid storage	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
Swine at agrienterprises							
Uncovered anaerobic lagoon	0.140	0.140	0.150	0.125	0.097	0.080	0.061
Liquid slurry	0.310	0.370	0.360	0.397	0.436	0.460	0.483
Solid storage	0.548	0.487	0.484	0.471	0.457	0.448	0.441
Composting	0.002	0.003	0.006	0.007	0.010	0.013	0.015
Aerobic treatment	NO	NO	NO	NO	NO	NO	NO
Swine in households							

MMS types	2010	2011	2012	2013	2014	2015	2016
Solid storage	1	1	1	1	1	1	1
Fur-bearing animals							
Solid storage	1	1	1	1	1	1	1
Rabbits							
Solid storage	1	1	1	1	1	1	1
Buffaloes							
Solid storage	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
Goats							
Solid storage	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
Camels							
Pasture/Range/Paddock	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
Horses							
Solid storage	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
Asses and mules							
Pasture/Range/Paddock	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
Poultry at agrienterprises							
Poultry manure without litter	0.993	0.990	0.994	0.992	0.968	0.998	0.995
Composting	0.007	0.010	0.006	0.008	0.032	0.002	0.005
Poultry in households							
Poultry manure without litter	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

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 of animals	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	19.69
Sows tested	0.06	17.59
Repair swine 4 months and older	0.06	5.28
Piglets up to 2 months	0.06	0.87
Piglets 2 to 4 months	0.06	5.28
Fattening swine	0.06	14.25
Boars	0.06	25.56
Swine in households		
Main sows	0.06	25.60
Repair swine 4 months and older	0.06	6.86
Piglets up to 2 months	0.06	1.14
Piglets 2 to 4 months	0.06	6.86
Fattening swine	0.06	18.53
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. Annual average N excretion per head of cattle and fur-bearing animals, kg N $animal^{-1}$ yr^{-1}

Cattle species	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cattle at agricultural enterprises										
Dairy cows	78.82	77.34	69.25	69.08	69.86	61.75	56.03	47.60	53.99	48.41
Heifers 2 years and older	38.36	37.58	37.01	37.93	39.31	37.88	36.49	33.20	34.27	35.29
Heifers from 1 to 2 years	30.80	30.19	29.75	30.47	31.52	30.36	29.19	26.54	27.38	28.21
Bulls	41.39	40.67	40.67	41.09	41.91	40.81	39.67	36.48	37.65	38.75
Beef cows	54.05	53.17	52.91	54.25	55.68	53.83	51.94	47.48	48.84	50.16
Cows on fattening	44.01	43.23	42.55	43.51	44.78	43.31	41.83	38.24	39.46	40.62
Other cattle and beef cattle fattening	18.16	17.80	17.58	18.06	18.72	18.05	17.37	15.56	16.13	16.68
Other cattle	16.12	15.05	14.25	14.07	13.23	10.17	9.17	6.04	10.95	6.34
Cattle at households										
Dairy cows	39.41	42.51	44.39	44.37	44.13	43.52	45.05	43.42	44.42	45.38
Heifers 2 years and older	29.33	28.74	28.71	28.10	28.46	29.36	30.30	31.37	32.18	33.03
Heifers from 1 to 2 years	22.90	22.51	22.57	22.05	22.41	22.96	23.50	24.28	24.99	25.70
Bulls	34.84	34.38	34.46	34.48	34.66	34.97	35.27	35.19	36.22	37.26
Other cattle	53.55	51.13	29.54	32.18	33.83	34.66	38.55	40.17	37.86	35.57
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

Cattle species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cattle at agricultural enterprises										
Dairy cows	47.36	56.59	62.85	58.00	65.24	75.61	79.66	75.41	81.36	96.64
Heifers 2 years and older	36.37	37.49	38.48	39.51	40.54	41.57	42.65	42.15	42.55	46.35
Heifers from 1 to 2 years	29.06	29.91	30.73	31.52	32.33	33.13	33.85	33.57	34.05	37.10
Bulls	39.83	40.91	41.99	43.06	44.11	44.97	45.18	44.89	45.99	49.95
Beef cows	51.53	52.93	54.22	55.61	57.28	58.97	59.01	57.65	58.97	64.35
Cows on fattening	41.80	42.96	44.05	45.14	46.24	47.34	48.09	47.74	47.96	52.15
Other cattle and beef cattle fattening	17.21	17.74	18.26	18.79	19.32	19.87	20.18	19.99	20.12	22.16
Other cattle	4.30	9.04	11.51	6.71	11.70	18.85	20.42	18.21	20.06	30.55
Cattle at households										
Dairy cows	46.31	46.96	48.69	49.25	50.83	55.57	58.88	56.47	57.59	57.58
Heifers 2 years and older	33.75	34.46	35.29	36.09	36.87	37.75	37.90	37.79	37.68	38.20

Cattle species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Heifers from 1 to 2 years	26.41	27.14	27.87	28.61	29.35	30.12	30.24	30.23	30.21	30.57
Bulls	38.33	39.41	40.48	41.55	42.64	43.72	43.19	43.34	43.24	43.65
Other cattle	37.10	33.22	29.42	31.80	37.72	35.62	35.72	36.02	40.01	40.68
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

Cattle species	2010	2011	2012	2013	2014	2015	2016
Cattle at agricultural enterprises							
Dairy cows	95.94	98.11	111.35	115.15	124.49	134.39	134.29
Heifers 2 years and older	45.00	44.28	46.31	46.10	48.44	49.75	48.94
Heifers from 1 to 2 years	36.00	35.39	36.97	36.90	38.90	39.84	39.09
Bulls	49.54	49.27	52.50	53.40	55.50	57.16	56.46
Beef cows	62.43	60.25	63.73	65.03	66.90	69.11	69.48
Cows on fattening	50.53	49.40	51.61	51.65	54.46	55.74	54.52
Other cattle and beef cattle fattening	21.36	20.80	21.88	21.95	23.27	23.94	23.47
Other cattle	30.03	27.13	31.55	33.57	36.31	37.38	40.02
Cattle at households							
Dairy cows	58.09	57.91	57.33	57.76	57.28	56.99	56.97
Heifers 2 years and older	38.29	38.49	38.62	38.53	38.49	38.46	38.44
Heifers from 1 to 2 years	30.56	30.67	30.65	30.51	30.49	30.47	30.47
Bulls	43.64	43.83	43.79	43.59	43.57	43.60	43.58
Other cattle	40.64	44.08	44.30	43.48	43.56	43.73	43.54
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

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	22 900	24 300	23 400	22 400	22 000	23 000	22 500	20 700	21 900
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	18 800	18 900	22 400	21 300	21 400	21 600	21 100	19 800	24 500
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
Annual harvested area	29 300	29 600	25 800	24 200	10 200	11 700	12 020
Standard organic fertilizer application	0.03	0.10	0.10	NO	NO	NO	NO

A3.2.5 Agricultural Soils

Table A3.2.5.1. Amount of fertilizers 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	546.06	521.80	463.43	439.38	418.81	361.19	312.29	248.48	237.58	219.21
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	12.98	NO	58.80	58.99	257.84	138.10	156.05
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	443.31	424.25	393.46	387.69	370.68	322.45	290.35	246.61	247.07	219.32

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	197.42	197.21	207.00	191.70	178.70	177.49	179.85	168.04	159.57	161.98
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	318.63	450.73	457.53	255.36	535.53	568.82	465.84	307.47	779.20	716.28
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	209.03	216.54	222.28	203.25	195.84	195.28	189.41	171.18	164.43	164.89

Data category	2010	2011	2012	2013	2014	2015	2016
Annual amount of N in synthetic fertilizers	774.83	899.05	928.57	1 041.14	1 052.80	1 015.92	1 248.04
Annual amount of N in organic fertilizers	162.02	158.54	161.34	165.50	162.47	155.47	150.55
Annual amount of N in crop residues	1 442.25	1 784.98	1 690.03	1 993.10	2 017.63	1 907.01	2 077.94
Annual amount of N in mineral soils that is mineralized	531.49	950.10	782.22	1 113.82	1 163.54	1 065.91	1 183.91
Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock	157.63	153.39	158.76	160.75	155.04	148.34	144.96

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	45.39	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	71.27	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
Polissia	102.63	125.88	142.02	180.62	183.15	179.58	192.74
Wooded Steppe	390.04	453.64	480.37	526.02	519.13	516.72	659.34
Steppe	282.16	319.53	306.18	334.50	350.52	319.62	395.96
of them for rice	3.99	4.65	3.58	3.73	1.70	2.04	2.04

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
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

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	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

Activity data	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
The amount of lime	169.70	191.10	143.80	132.00	222.80	243.10	283.40	300.40	334.10	406.10

Activity data	2010	2011	2012	2013	2014	2015	2016
The amount of lime	340.80	340.00	432.40	487.30	417.80	454.10	374.59

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
Cropland	456.45	533.89	479.13	520.57	526.40	507.96	624.02

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 and age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agrienterprises										
Cows	113.3	112.3	102.4	100.9	98.5	92.5	88.2	83.1	91.8	81.2
Heifers 2 years and older	66.0	66.6	67.9	67.6	67.8	68.4	69.3	69.9	69.7	69.4
Heifers from 1 to 2 years	53.5	53.9	54.8	54.5	54.6	55.1	55.6	56.0	55.9	55.7
Bulls	71.0	71.2	72.0	71.8	71.8	72.4	73.0	73.4	73.3	73.1
Beef cows	79.7	80.7	82.4	81.9	81.9	83.0	84.3	85.1	84.9	84.6
Cows on fattening	89.1	90.0	92.6	92.1	92.4	93.4	94.4	94.9	94.4	93.8
Cattle on fattening (excluding cows)	43.4	43.7	44.7	44.5	44.6	45.1	45.6	45.9	45.7	45.5
Other cattle	37.5	36.5	36.1	35.0	32.9	29.2	28.6	25.6	33.5	24.8
Households										
Cows	94.2	101.1	102.4	103.5	102.4	101.0	102.5	100.5	100.8	101.1
Heifers 2 years and older	67.9	67.8	67.7	67.5	67.3	67.5	67.8	67.9	68.3	68.6
Heifers from 1 to 2 years	54.7	54.7	54.6	54.6	54.5	54.6	54.7	54.6	54.8	55.0
Bulls	74.6	74.5	74.2	74.3	74.4	74.4	74.3	74.2	74.7	75.1
Other cattle	127.0	123.0	77.8	84.4	86.1	85.9	91.8	92.6	86.5	80.5

Sex and age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agrienterprises										
Cows	76.0	89.0	94.9	84.9	93.8	106.1	107.9	105.6	107.9	116.9
Heifers 2 years and older	69.3	69.2	68.9	68.6	68.5	68.3	67.4	67.7	66.6	66.7
Heifers from 1 to 2 years	55.6	55.5	55.3	55.1	54.9	54.7	54.1	54.3	53.5	53.5
Bulls	73.0	72.8	72.6	72.4	72.2	72.0	71.4	71.8	71.1	71.0
Beef cows	84.5	84.3	84.1	83.8	83.7	83.4	82.4	83.0	81.7	81.5
Cows on fattening	93.3	92.7	92.2	91.7	91.3	90.9	89.4	89.8	87.7	87.9
Cattle on fattening (excluding cows)	45.3	45.2	45.0	44.8	44.6	44.4	43.8	44.0	43.2	43.2
Other cattle	20.8	28.0	31.3	23.1	30.3	40.3	41.5	38.6	40.4	51.5
Households										
Cows	101.9	102.3	104.6	104.1	106.6	114.2	122.9	118.6	121.8	121.4
Heifers 2 years and older	68.8	68.9	69.2	69.5	69.7	70.1	70.2	70.6	70.9	70.2
Heifers from 1 to 2 years	55.2	55.4	55.7	55.9	56.1	56.3	56.3	56.4	56.5	56.1

Sex and age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bulls	75.6	76.1	76.6	77.0	77.5	77.9	78.1	78.0	78.1	77.9
Other cattle	81.7	73.3	65.2	68.1	76.9	72.0	72.1	72.9	79.7	79.7

Sex and age group	2010	2011	2012	2013	2014	2015	2016
Agrienterprises							
Cows	116.0	117.0	124.0	125.9	131.1	135.9	138.6
Heifers 2 years and older	66.8	66.8	66.3	66.4	67.1	67.0	66.8
Heifers from 1 to 2 years	53.6	53.6	53.2	53.3	53.6	53.5	53.4
Bulls	70.8	70.7	70.3	70.4	70.7	70.4	70.2
Beef cows	81.3	81.4	80.5	80.8	82.2	82.2	82.0
Cows on fattening	87.9	87.6	86.7	86.8	87.8	87.5	87.1
Cattle on fattening (excluding cows)	43.3	43.3	42.8	42.9	43.3	43.2	43.1
Other cattle	52.4	48.9	52.9	55.6	56.6	56.7	61.3
Households							
Cows	122.3	122.2	122.0	124.3	124.8	124.1	124.1
Heifers 2 years and older	70.0	69.6	69.6	69.7	69.6	69.5	69.6
Heifers from 1 to 2 years	56.0	55.9	55.8	56.0	55.9	55.9	56.0
Bulls	77.9	77.8	77.8	77.9	78.0	77.9	77.9
Other cattle	79.5	84.5	84.8	83.8	84.0	84.2	83.9

Table A3.2.8.2. Estimation of emission factors from enteric fermentation of dairy herd of cows and their uncertainty

Indicator	Agrienterprises			Households		
	1990	2015	Uncertainty, %	1990	2015	Uncertainty, %
Cow population, heads	6 273 050.00	507 832.00	6	2 179 850.00	1 724 994.00	6
Consumption of all feeds (concentrated, coarse, succulent, and other) vs live-stock, kt, f.u.	30 298.67	2 979.35	6	7 828.33	7 950.38	6
Consumption of other fodder, based on the feed ration structure, kt, f.u.	5 130.19	142.61	6	2 543.18	3 895.69	6
Consumption of coarse fodder, based on the feed ration structure, kt, f.u.	4 906.44	606.06	6	1 811.99	2 385.11	6
Consumption of succulent fodder, based on the feed ration structure, kt, f.u.	13 303.92	1 046.10	6	2 929.76	986.62	6
Consumption of concentrated fodder, based on the feed ration structure, kt, f.u.	6 958.12	1 184.58	6	543.40	682.96	6
Weighted average rates of energy nutri-tionally of other fodders, f.u.	0.18	0.18	4.99	0.18	0.18	4.96
Weighted average rates of energy nutri-tionally of coarse fodders, f.u.	0.50	0.47	17.69	0.47	0.48	17.05
Weighted average rates of energy nutri-tionally of succulent fodders, f.u.	0.19	0.17	18.10	0.18	0.18	17.30
Weighted average rates of energy nutri-tionally of concentrated fodders, f.u.	1.09	1.05	8.41	1.07	1.08	8.15
Consumption of other fodder, kt	28 231.07	800.44	9.27	14 319.74	21 710.73	9.25
Consumption of coarse fodder, kt	9 746.96	1 296.65	19.33	3 868.27	4 821.49	18.75
Consumption of succulent fodder, kt	70 631.92	6 008.30	19.71	16 632.47	5 673.22	18.98
Consumption of concentrated fodder, kt	6 403.25	1 132.27	11.48	509.51	632.90	11.29
Weighted average amount of GE in 1 kg of other fodders, MJ	3.76	3.64	6.81	3.68	3.72	6.66
Weighted average amount of GE in 1 kg of coarse fodders, MJ	14.95	14.93	1.98	15.05	15.03	1.97
Weighted average amount of GE in 1 kg of succulent fodders, MJ	3.60	3.40	13.49	3.41	3.50	13.08
Weighted average amount of GE in 1 kg of concentrated fodders, MJ	15.99	15.54	8.73	16.09	16.13	8.41
GE in feed rations, MJ head^{-1} per day	265.68	325.10	9.72	220.97	291.12	8.72
Methane conversion factor, rel. u.	0.065	0.065	8	0.065	0.065	8
Emission factor, kg head^{-1}	113.27	138.60	12.59	94.20	124.11	11.84

Table A3.2.8.3. Methane emission factors from enteric fermentation of sheep, kg head^{-1}

Sex and age group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Ewes and gimmers 1 year and older	8.88	8.84	8.83	8.84	8.85	8.85	8.87	8.97	9.02	9.08
Rams	13.30	13.28	13.27	13.27	13.26	13.20	13.19	13.22	13.20	13.22
Wethers	7.55	7.54	7.53	7.53	7.52	7.49	7.48	7.50	7.49	7.50
Fattening livestock	6.24	6.23	6.22	6.22	6.21	6.19	6.18	6.20	6.19	6.20
Lambs up to 4 months and 4-12 months repair young sheep	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 and age group	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ewes and gimmers 1 year and older	9.21	9.31	9.34	9.21	9.76	9.45	9.54	9.62	9.51	9.24
Rams	13.09	13.12	13.13	12.82	12.85	12.87	12.89	12.91	12.89	12.91
Wethers	7.50	7.53	7.54	7.54	7.55	7.57	7.58	7.58	7.57	7.58
Fattening livestock	6.20	6.22	6.23	6.23	6.24	6.25	6.26	6.26	6.25	6.26
Lambs up to 4 months and 4-12 months repair young sheep	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 and age group	2010	2011	2012	2013	2014	2015	2016
Ewes and gimmers 1 year and older	9.52	10.06	10.02	10.00	9.90	9.86	9.75
Rams	12.90	12.97	12.96	12.94	12.94	12.93	12.92
Wethers	7.55	7.55	7.54	7.53	7.52	7.52	7.51
Fattening livestock	6.24	6.24	6.23	6.22	6.22	6.21	6.21
Lambs up to 4 months and 4-12 months repair young sheep	5.63	5.63	5.62	5.61	5.61	5.60	5.60
Average weighted emission factor	*8.71*	*9.01*	*8.89*	*8.86*	*8.78*	*8.74*	*8.65*

Table A3.2.8.4. Methane emission factors from enteric fermentation and manure management, kg 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 A3.2.8.5. Methane emission factors from manure management of cattle, swine, sheep, and poultry, kg of CH_4 $head^{-1}$

Species and groups of animals	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Agrienterprises										
Cows	8.34	8.35	6.93	6.61	5.94	5.07	4.64	3.68	3.68	3.26
Heifers 2 years and older	5.33	5.42	5.01	4.83	4.47	4.09	3.97	3.38	3.06	3.04
Heifers from 1 to 2 years	2.93	2.96	2.72	2.62	2.41	2.21	2.14	1.82	1.65	1.64
Bulls	3.50	3.54	3.26	3.14	2.90	2.66	2.58	2.19	1.98	1.97
Beef cows	4.53	4.66	4.32	4.17	3.85	3.54	3.45	2.92	2.65	2.64
Cows on fattening	4.90	5.01	4.68	4.52	4.19	3.84	3.73	3.14	2.83	2.82
Cattle on fattening (excluding cows)	2.36	2.42	2.24	2.17	2.01	1.84	1.79	1.51	1.36	1.36
Other cattle	2.05	2.00	1.79	1.68	1.45	1.17	1.10	0.83	0.99	0.73
Main sows	4.08	3.90	3.56	3.22	2.90	5.98	6.08	6.55	6.55	6.55
Sows tested	3.65	3.48	3.18	2.87	2.59	5.34	5.43	5.85	5.85	5.85
Repair swine 4 months and older	1.09	1.04	0.95	0.86	0.78	1.60	1.63	1.76	1.76	1.76
Piglets up to 2 months	0.18	0.17	0.16	0.14	0.13	0.27	0.27	0.29	0.29	0.29
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	2.95	2.82	2.58	2.33	2.10	4.33	4.40	4.74	4.74	4.74
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	3.25	3.48	3.53	3.56	3.52	3.47	3.53	3.45	3.46	3.46
Heifers 2 years and older	2.34	2.33	2.33	2.32	2.31	2.32	2.33	2.35	2.35	2.37
Heifers from 1 to 2 years	1.39	1.38	1.38	1.38	1.37	1.38	1.38	1.39	1.39	1.39
Bulls	1.75	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.75
Other cattle	3.22	3.11	1.97	2.13	2.17	2.17	2.32	2.35	2.19	2.03
Main sows	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19
Repair swine 4 months and older	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Piglets up to 2 months	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
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	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58

Species and groups of animals	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

Species and groups of animals	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agrienterprises										
Cows	2.73	3.20	3.41	3.05	3.36	3.80	4.28	4.18	4.45	4.88
Heifers 2 years and older	2.73	2.72	2.71	2.70	2.69	2.68	2.92	2.94	3.00	3.05
Heifers from 1 to 2 years	1.47	1.47	1.46	1.46	1.45	1.44	1.58	1.58	1.62	1.64
Bulls	1.77	1.76	1.75	1.75	1.74	1.73	1.90	1.91	1.97	1.99
Beef cows	2.37	2.36	2.36	2.35	2.34	2.33	2.54	2.56	2.61	2.63
Cows on fattening	2.51	2.49	2.48	2.47	2.45	2.44	2.65	2.67	2.70	2.75
Cattle on fattening (excluding cows)	1.21	1.21	1.20	1.20	1.19	1.19	1.29	1.30	1.32	1.34
Other cattle	0.55	0.74	0.82	0.61	0.80	1.06	1.20	1.12	1.22	1.57
Main sows	6.72	6.79	7.06	7.19	7.13	8.47	8.14	9.21	10.56	10.89
Sows tested	6.00	6.06	6.30	6.42	6.36	7.57	7.27	8.23	9.43	9.73
Repair swine 4 months and older	1.80	1.82	1.89	1.93	1.91	2.27	2.18	2.47	2.83	2.92
Piglets up to 2 months	0.30	0.30	0.31	0.32	0.32	0.38	0.36	0.41	0.47	0.48
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	4.87	4.91	5.11	5.21	5.16	6.13	5.89	6.67	7.64	7.89
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

Species and groups of animals	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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	3.48	3.48	3.55	3.53	3.60	3.85	4.15	4.00	4.11	4.09
Heifers 2 years and older	2.37	2.37	2.38	2.38	2.39	2.40	2.40	2.42	2.43	2.40
Heifers from 1 to 2 years	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.40	1.38
Bulls	1.76	1.77	1.78	1.78	1.79	1.80	1.80	1.80	1.80	1.80
Other cattle	2.05	1.83	1.63	1.69	1.90	1.78	1.78	1.80	1.97	1.96
Main sows	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19
Repair swine 4 months and older	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Piglets up to 2 months	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
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	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
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

Species and groups of animals	2010	2011	2012	2013	2014	2015	2016
Agrienterprises							
Cows	4.92	4.86	5.20	5.36	5.66	5.91	6.10
Heifers 2 years and older	3.09	3.03	3.02	3.06	3.15	3.17	3.20
Heifers from 1 to 2 years	1.66	1.63	1.62	1.65	1.68	1.69	1.70
Bulls	2.01	1.97	1.98	2.01	2.05	2.06	2.09
Beef cows	2.67	2.61	2.59	2.65	2.75	2.79	2.87
Cows on fattening	2.78	2.72	2.70	2.74	2.83	2.85	2.87
Cattle on fattening (excluding cows)	1.36	1.33	1.33	1.35	1.39	1.40	1.41
Other cattle	1.62	1.48	1.61	1.71	1.77	1.79	1.95
Main sows	11.30	11.70	12.17	11.07	9.80	9.05	8.22
Sows tested	10.09	10.45	10.87	9.89	8.76	8.08	7.34
Repair swine 4 months and older	3.03	3.14	3.26	2.97	2.63	2.43	2.20
Piglets up to 2 months	0.50	0.52	0.54	0.49	0.44	0.40	0.36
Piglets 2 to 4 months	3.03	3.14	3.26	2.97	2.63	2.43	2.20
Fattening swine	8.18	8.47	8.81	8.02	7.10	6.55	5.95
Boars	14.67	15.19	15.80	14.38	12.73	11.75	10.67
Hens and roosters	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
Ducks	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
Other poultry	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Households							
Cows	4.12	4.12	4.11	4.19	4.21	4.18	4.18
Heifers 2 years and older	2.39	2.38	2.37	2.38	2.38	2.37	2.37
Heifers from 1 to 2 years	1.38	1.38	1.37	1.38	1.38	1.38	1.38
Bulls	1.80	1.79	1.79	1.80	1.80	1.80	1.80
Other cattle	1.96	2.08	2.08	2.06	2.06	2.07	2.06
Main sows	2.19	2.19	2.19	2.19	2.19	2.19	2.19
Repair swine 4 months and older	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Piglets up to 2 months	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Piglets 2 to 4 months	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Fattening swine	1.58	1.58	1.58	1.58	1.58	1.58	1.58
Boars	2.84	2.84	2.84	2.84	2.84	2.84	2.84

Species and groups of animals	2010	2011	2012	2013	2014	2015	2016
Hens and roosters	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
Ducks	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
Other poultry	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	0.24	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
Wethers	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
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

Table A3.2.8.6. 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 A3.2.8.7 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
Adjusted daily emission factor	2.47	2.48	2.48	2.47	2.47	2.47	2.47

Table A3.2.8.8. Coefficients for calculation indirect nitrous oxide emissions from agricultural soils

Coefficient name	Units	Values
$Frac_{GASF}$ (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

A3.3 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 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.

From the database of activities regulated by Article 3.3 of the Kyoto Protocol, actual data on afforestation and deforestation were used. The information is presented based on the cumulative approach and 20-years transition period - Table A3.3.1.

Table A3.3.1. Land areas converted to and from the land-use category Forest land, 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
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

Special attention should be paid to the situation regarding determination of data of the area of land converted to Forest land. Ukraine is working on filling in the database for the activity features in accordance with paragraph 3, Article 3 of the Kyoto Protocol. Description of the database development process is presented in Chapter 11. This chapter presents the areas of land taken for the estimation.

In order to reflect actual values of converted areas to and from forests, the decision was made to use for the both cases information from the database. This improves reliability of the results, since the raw 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 6-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 [22].

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 6-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 and dead organic matter pools. For forest soils, the decision on the zero carbon balance was made, based on the studies [4].

The annual increase in carbon stocks in living biomass of Forest land remaining forest land was estimated under Formula 2.9 of the 2006 IPCC Guidelines [1] in the context of the key forest tree species and climatic zones.

The classification (Table A3.3.2) was used for distribution of areas into zones.

Table A3.3.2. Distribution of the forest area of Ukrainian regions' territory by climatic zones, relative units

Regions	Polissia (Woodland)	Wooded 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		

Regions	Polissia (Woodland)	Wooded Steppe	North Steppe	South Steppe	Carpathian Mts.	Crimean Mts.
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 A3.3.3 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. The last column "Aggregated Factor Value" is the value of the total carbon uptake by living biomass, i.e. it includes above-ground and below-ground ones.

Table A3.3.3. Biomass growth by natural zones and species for Forest land remaining forest land (national data), t/ha/yr

Natural zones and species	Increase in above-ground bi-omass	Ratio of below-ground and above-ground biomass growth	Aggregated value of the factors
			<u>Polissia</u>
Pine	3.60	0.16	4.18
Spruce	5.00	0.15	5.75
Other conifers	4.20	0.14	4.79
Oak	3.30	0.16	3.83
Other hardwood	3.10	0.14	3.53
Birch	3.40	0.12	3.81
Alder	3.50	0.12	3.92
Aspen	3.20	0.12	3.58
Other softwood	3.10	0.12	3.47
Other tree species	3.00	0.12	3.36
			<u>Wooded Steppe</u>
Pine	3.40	0.16	3.94
Spruce	5.00	0.14	5.70
Other conifers	3.50	0.14	3.99
Oak	3.20	0.16	3.71
Beech	4.00	0.14	4.56
Other hardwood	3.80	0.15	4.37
Birch	3.30	0.12	3.70
Alder	3.40	0.12	3.81
Aspen	3.20	0.12	3.58
Other softwood	3.10	0.12	3.47
Other tree species	3.00	0.12	3.36
			<u>North Steppe</u>
Pine	2.60	0.17	3.04
Oak	3.00	0.17	3.51
Other hardwood	2.80	0.15	3.22

Natural zones and species	Increase in above-ground biomass	Ratio of below-ground and above-ground biomass growth	Aggregated value of the factors
Birch	3.20	0.12	3.58
Alder	3.30	0.12	3.70
Aspen	3.10	0.12	3.47
Other softwood	3.00	0.12	3.36
Other tree species	3.00	0.12	3.36
South Steppe			
Pine	2.40	0.17	2.81
Oak	3.00	0.17	3.51
Other hardwood	2.80	0.15	3.22
Birch	3.10	0.12	3.47
Alder	3.20	0.12	3.58
Other softwood	2.80	0.12	3.14
Other tree species	2.80	0.12	3.14
Carpathian Mts.			
Pine	3.40	0.15	3.91
Spruce	5.40	0.14	6.16
Other conifers	5.00	0.14	5.70
Oak	3.40	0.15	3.91
Beech	4.20	0.15	4.83
Other hardwood	4.00	0.14	4.56
Birch	3.40	0.12	3.81
Alder	3.50	0.12	3.92
Aspen	3.20	0.12	3.58
Other softwood	3.00	0.12	3.36
Other tree species	3.20	0.12	3.58
Crimean Mts.			
Pine	2.40	0.16	2.78
Other conifers	2.20	0.15	2.53
Oak	2.20	0.17	2.57
Beech	2.80	0.15	3.22
Other hardwood	2.50	0.14	2.85
Birch	3.10	0.12	3.47
Alder	3.20	0.12	3.58
Aspen	3.00	0.12	3.36
Other softwood	2.80	0.12	3.14
Other tree species	2.80	0.12	3.14
Shrubs (all zones)	*0.4*	*1.25*	*0.90*

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 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 1990-2016 was obtained based on data of the State Statistics Service of Ukraine and the State Forest Resources Agency of Ukraine (Table A3.3.4).

Table A3.3.4. Harvesting volumes (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
*Data of the State Statistic Service of Ukraine, corrected using analytical study [3]	

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 previously used with biomass expansion factors and wood density was applied. Table A3.3.5 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 A3.3.5.

Moreover, Table A3.3.5 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 A3.3.5. 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		0.42
Spruce (Picea)	0.77	0.14		0.36
Fir (Abies)	0.77	0.14		0.40
Other conifers	0.77	0.14		0.40
Oak (Quercus)	0.89	0.16		0.56
Beech (Fagus)	0.89	0.15		0.58

	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
Ash (Fraxinus)	0.89	0.15		0.56
Hornbeam (Carpinus)	0.89	0.15		0.63
Other hardwood	0.89	0.15		0.56
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 A3.3.5 tables was converted into dry matter.

Considering the proportion of biomass losses as a result of disturbances for 1990-2013, it was determined by introducing a correction factor from 2014 data, since 2006 IPCC does not determine this parameter by default. For the first time since 2014 national statistics gather actual information on timber losses due to disturbances. It was therefore possible to determine timber losses by the average stock of wood stands in Ukraine and the loss area and to compare them with the actual figures. The results of this comparison for 1990-2014 are shown in Table A3.3.6. Moreover, it should be noted that the State Statistic Service of Ukraine introduced this new reporting form with no separation of coniferous and deciduous trees in statistical reporting. Therefore, the ratios obtained based on 2013 data were used.

For delivering of losses of wood for 2014-2016 actual data was used from the State Statistic Service of Ukraine.

Table A3.3.6. Determination of the correction factor relative to actual losses of wood at disturbance events

Region	Area, ha		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	Coniferous	Deciduous
Ukraine	12107	3245	3630989	560867	2600573	561937		
AR Crimea	0	0	0	0	0	0	1	0.38
Vinnytska	394	61	102170	13681	33773	5227	0.33	0.75
Volynska	1140	271	285141	48476	151887	36164	0.53	0.77
Dnipropetrovska	11	33	2658	5813	1558	4468	0.59	0.08
Donetska	22	48	4889	8825	328	722	0.07	0.92
Zhytomyrska	1309	33	355567	6778	246098	6267	0.69	1.36
Transcarpathian	1467	551	598721	143109	518837	195002	0.87	1.02
Zaporizhska	0	6	39	770	41	784	1.06	1.18
Ivano-Frankivska	1077	24	349391	5356	281079	6342	0.80	1.84
Kyivska	1	0	221	45	283	82	1.28	1.04
Kirovohradska	56	477	11796	88273	10699	91885	0.91	0.53
Luganska	212	113	47632	17609	17588	9401	0.37	0.66
Lvivska	818	135	237573	30342	120644	19896	0.51	0.91
Mykolaivska	16	148	2047	14177	1435	12913	0.70	0.99
Odesska	7	344	703	52025	1002	51526	1.43	1
Poltavska	0	0	0	0	0	0	1	0.81
Rivnenska	2497	119	565306	21187	361086	17218	0.64	1.18
Sumska	415	47	151998	11790	122626	13940	0.81	0.82

Region	Area, ha		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	Coniferous	Deciduous
Ternopilska	43	90	11487	18201	7280	15014	0.63	0.79
Kharkivska	16	4	4763	902	2891	710	0.61	0.02
Khersonska	129	71	19751	7886	217	119	0.01	1.35
Khmelnytska	256	86	76119	17676	70595	23830	0.93	0.99
Cherkaska	537	126	151257	26774	112848	26492	0.75	1.11
Chernivetska	987	71	308745	16592	257308	18411	0.83	1.21
Chernihivska	977	21	318515	4582	257488	5524	0.81	1
Kyiv city	86	0	24501	0	22982	0	0.94	1
Sevastopol	0	0	0	0	0	0	1	0.38

Table A3.3.7. 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
Dnipropetrovska	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
Transcarpathian	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-Frankivska	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	
	Coniferous	Decidious	Coniferous	Decidious
Ukraine, in average	**281**	**219**	**284**	**224**
AR Crimea	168	154	174	160
Vinnytska	261	242	262	243
Volynska	252	170	252	171
Dnipropetrovska	253	162	256	171
Donetska	225	163	227	171
Zhytomyrska	275	203	278	205
Transcarpathian	410	352	418	358
Zaporizhska	137	84	145	92
Ivano-Frankivska	327	253	335	264
Kyivska	287	206	296	212
Kirovohradska	219	189	222	192
Luganska	232	146	230	152
Lvivska	287	258	287	265
Mykolaivska	101	118	132	81
Odesska	131	74	113	144
Poltavska	112	137	283	221
Rivnenska	280	214	229	174
Sumska	228	172	374	275
Ternopilska	368	269	274	216
Kharkivska	268	212	297	241
Khersonska	295	234	142	90
Khmelnytska	139	85	305	222
Cherkaska	299	217	291	233
Chernivetska	286	229	303	263
Chernihivska	308	264	331	222
Kyiv city	287	206	296	212
Sevastopol	168	154	124	125

The average stock of biomass in forested forest land of the State Forest Resources Agency of Ukraine is presented in Table A3.3.7. 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.

Emissions from above-ground biomass at fires are not included into 4.A CSC in Forest Land CRF reporting table and were reported separately in CRF reporting table Table 4(V).

Forest fires in Ukraine traditionally are divided into 3 groups according to burnt biomass:

- Ground 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 1990-2016 is presented in Table A3.3.8. It should be noticed that for the years 2014-2016 the data was corrected using analytical study.

Table A3.3.8. 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
	Ground	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
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
*Data of the State Statistic Service of Ukraine, corrected using analytical study [3]					

To estimate carbon emissions from fires, equation 2.14 of 2006 IPCC Guidelines was adapted to the above-mentioned classification (A3.3.1). Accordingly, the emissions were estimated using the following method:

$$L_{fires} = \left(L_{ground} + L_{crown} + L_{underground} + L_{harvested}\right) \times G_{ef} \times 10^{-6} \qquad \text{(A3.3.1)}$$

где L_{fires} – total emissions from fires, kt C;

L_{ground} – biomass losses in ground fires, t d.m.;

L_{crown} – biomass losses in crown fires, t d.m.;

$L_{underground}$ – biomass losses in 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:

$$L_{ground} = A_{ground} \times B_{litter} \times CF_{organic\ matter} \quad (A3.3.2)$$

$$L_{crown} = A_{crown} \times B_{litter} \times CF_{organic\ matter} + \\ +W_{wood} \times BCEF_R \times (1+R) \times C_f \times CF \quad (A3.3.3)$$

$$L_{underground} = A_{underground} \times B_{organic\ matter} \times CF_{organic\ matter} \quad (A3.3.4)$$

$$L_{harvested} = W_{harvested} \times D \times CF \quad (A3.3.5)$$

where A is the area affected by fires: respectively, ground, 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 [10], 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 A3.3.5) 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 A3.3.5). G_{ef} coefficients were taken by default from Table 2.5 of 2006 IPCC.

During crown fires in standings it is assumed that all biomass is lost – above- and below-ground. But with 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 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.3.3.3.

CO_2 emissions from liming on forest land were not calculated, since this type of activity is not performed in the forestry sector.

N_2O emissions from fertilizer application were not estimated due to lack of fertilizer application in forestry.

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 A3.3.9).

Table A3.3.9. 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

Natural zones and species	Increase in above-ground biomass	Ratio of below-ground and above-ground bio-mass growth	Aggregated value of the factors adopted for esti-mation
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
			Wooded 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
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 subcategory areas (4.A.1 and 4.A.2), as well as values of the average annual change in carbon stock in litter (equations A3.3.6 and A3.3.7):

$$\Delta C_{DW} = A \times \Delta B_{DW}, \qquad (A3.3.6)$$

where A is the area of the respective sub-category, ha;
ΔB_{DW} - changes in carbon stock in deadwood per unit of area, t C/ha/year.

$$\Delta C_{LT} = A \times \Delta B_{LT}, \qquad (A3.3.7)$$

where A is the area of the respective sub-category, ha;
ΔB_{LT} - changes in carbon stock in litter per unit of area, t C/ha/year.

The values of carbon stock changes in deadwood and litter for sub-categories 4.A.1 and 4.A.2 differ and are presented in Tables A3.3.10 and A3.3.11, respectively.

Table A3.3.10. Carbon stock changes in the litter pool (t C/ha) and changes in stocks of deadwood on Forest land remaining forest land

Changes in carbon stock in litter, t C/ha										
Age group	10 and <	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Coniferous	0.1	0.09	0.07	0.06	0.04	0.03	0.01	0	-0.01	-0.03
Deciduous	0.08	0.05	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01
Deadwood stock, m^3/ha										
Research cycle	D_2-Oak		B_2-Pine		C_2-Oak		C_2-Pine		Total	
	1	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
1999-2002	8.1	5.0	8.3	0.6	2.2	0	14.2	4.5	8.8	3.9
2003-2006	9.3	7.8	3.6	6.2	5.9	6.7	7.6	16.9	7.5	7.0

Table A3.3.11. Carbon stock change in litter and deadwood pools on Land converted to Forest land, t C/ha

Nature zone	Tree species						
	Pine	Spruce	Other conifers	Oak	Beech	Other hardwood	Softwood
Litter							
Polissia	0.4	0.4	0.3	0.2	0.2	0.2	0.2
Wooded Steppe	0.3	0.3	0.3	0.3	0.3	0.3	0.3
North Steppe	0.3	-	-	0.3	-	0.3	0.3
South Steppe	0.3	-	-	0.3	-	0.3	0.3
Carpathian Mts.	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Crimean Mts.	0.4	-	0.3	0.3	0.3	0.3	0.3
Deadwood							
Polissia	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Wooded Steppe	0.1	0.2	0.1	0.1	0.1	0.1	0.1
North Steppe	0.2	-	-	0.1	-	0.1	0.1
South Steppe	0.2	-	-	0.1	-	0.1	0.1
Carpathian Mts.	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Crimean Mts.	0.1	-	0.2	0.2	0.2	0.2	0.2

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 Land converted to forest land was held under Tier 1 with application of default factors. Particularly according to Harmonized World Soil Database v.1.2 almost all of the mineral soils (in terms of IPCC classification) in Ukraine are high-activity clays with insignificant part of sandy soils. Thus reference soil organic C stocks for HAC were applied.

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 6-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 A3.3.12). Any changes in the total area from 6-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 A3.3.12. 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
1	26,07	29,67	28,67	27,57	27,97	29,57	28,37	28,07	28,77	27,77	28,37
2	26,47	26,07	29,67	28,67	27,57	27,97	29,57	28,37	28,07	28,77	27,77
3	23,97	26,47	26,07	29,67	28,67	27,57	27,97	29,57	28,37	28,07	28,77
4	23,57	23,97	26,47	26,07	29,67	28,67	27,57	27,97	29,57	28,37	28,07
5	21,37	23,57	23,97	26,47	26,07	29,67	28,67	27,57	27,97	29,57	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
7	20,22	22,57	21,37	23,57	23,97	26,47	26,07	29,67	28,67	27,57	27,97
8	20,22	20,22	22,57	21,37	23,57	23,97	26,47	26,07	29,67	28,67	27,57
9	8,32	20,22	20,22	22,57	21,37	23,57	23,97	26,47	26,07	29,67	28,67
10	8,32	8,32	20,22	20,22	22,57	21,37	23,57	23,97	26,47	26,07	29,67
11	20,27	8,32	8,32	20,22	20,22	22,57	21,37	23,57	23,97	26,47	26,07
12	12,77	20,27	8,32	8,32	20,22	20,22	22,57	21,37	23,57	23,97	26,47
13	20,47	12,77	20,27	8,32	8,32	20,22	20,22	22,57	21,37	23,57	23,97
14	34,67	20,47	12,77	20,27	8,32	8,32	20,22	20,22	22,57	21,37	23,57
15	20,37	34,67	20,47	12,77	20,27	8,32	8,32	20,22	20,22	22,57	21,37
16	19,37	20,37	34,67	20,47	12,77	20,27	8,32	8,32	20,22	20,22	22,57
17	28,37	19,37	20,37	34,67	20,47	12,77	20,27	8,32	8,32	20,22	20,22
18	28,37	28,37	19,37	20,37	34,67	20,47	12,77	20,27	8,32	8,32	20,22
19	28,37	28,37	28,37	19,37	20,37	34,67	20,47	12,77	20,27	8,32	8,32
20	28,37	28,37	28,37	28,37	19,37	20,37	34,67	20,47	12,77	20,27	8,32
21	28,37	28,37	28,37	28,37	28,37	19,37	20,37	34,67	20,47	12,77	20,27
22	28,37	28,37	28,37	28,37	28,37	28,37	19,37	20,37	34,67	20,47	12,77
23	28,37	28,37	28,37	28,37	28,37	28,37	28,37	19,37	20,37	34,67	20,47
24	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	19,37	20,37	34,67
25	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	19,37	20,37
26	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	19,37
27	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37	28,37
28	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
30	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	1524,81	1527,54	1528,17	1526,49	1525,65	1528,17	1528,17	1527,54	1528,38	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

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 [26, 27, 28, 29, etc.] and originates from the Soviet practice of the soil science [30-36 et al.]. 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 [37, 38], and also was published [9, 39]. 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 is its removal with:
  - the yield of main products;
  - post-harvest crop residues;
  - by-products;
  - roots.

Beside, 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 A3.3.8:

$$\overline{C_r} = (\sum N_{D_i} + \sum N_j - \sum N_{M_{is}}) \times k_{C:N_s}, \quad \text{(A3.3.8)}$$

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 A3.3.8 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 A3.3.9:

$$N_{D_i} = \sum_{Rs_i}[(B \times \eta - N_{CR}) \times k] + \sum_{Rt_i}[(B \times \eta - N_{CR}) \times k], \quad \text{(A3.3.9)}$$

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 [40], Table A3.3.13; their humification factors - Table A3.3.14 [27, 32], and their nitrogen content - Table A3.3.15 [33].

Table A3.3.13. 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 A3.3.14. 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, Wooded Steppe			Steppe	Polissia	Wooded 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 A3.3.15. Nitrogen content in crop plant residues, %

Crop	Above-ground residues	Roots
Winter rye	0.45	0.75
Winter wheat	0.45	0.75
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

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 A3.3.10:

$$N_j = N'_j \times k_r, \qquad \text{(A3.3.10)}$$

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 A3.3.11:

$$N'_j = (N_{Aj} - V_m) \times d_j, \qquad \text{(A3.3.11)}$$

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.

The direct emissions of nitrogen released annually at application of organic fertilizer is calculated in the Agriculture category.

Conversion factors for the different types of organic fertilizers to the equivalent amount of standard bedding manure are presented in Table A3.3.16. The humification of bedding manure factor [28] is for Polissia 0.042, Wooded Steppe 0.054, Steppe 0.059.

Table A3.3.16. 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
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 [41] - 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 A3.3.17) [27].

Table A3.3.17. 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 3.3.8 is the sum of the amount of mineralized humus in the inventory year in view of the crop and soil type (A3.3.12):

$$N_{M_{is}} = \left[N_i^* - \left(\frac{N_{fi}+N_{ri}}{2} + v_j \times N_j\right)\right] \times k_{mnr}, \quad \text{(A3.3.12)}$$

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 A3.4.18);
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 A3.3.18. 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 A3.3.19 [42].

Table A3.3.19. 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
						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

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	
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 (fi-ber)	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						
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						

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	
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 3.3.13 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:

$$k_{mnr} = k_i \times k_s, \qquad \text{(A3.3.13)}$$

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 A3.3.20 and 3.3.21, respectively [28].

Table A3.3.20. The factors to account the type of agricultural crops at soil humus mineralization, relative units

Crop	Soil and climatic zone		
	Polissia	Wooded 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

Crop	Soil and climatic zone		
	Polissia	Wooded Steppe	Steppe
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 A3.3.21. 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 A3.3.22 [43].

Table A3.3.22. 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 Wooded 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
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

Types of soil	Humus content, %	Organic C in the general initial soil, %	Gross nitrogen, %	C:N
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 A3.3.23) [42], as well as take into account the distribution of soil types by natural zones (Table A3.3.24) [44].

Table A3.3.23. 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 A3.3.24. 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

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
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 A3.3.25.

Table A3.3.25. Distribution of areas damaged by fires by agricultural crops, ha

Crop	2005	2010	2011	2012	2013	2014	2015	2016
Wheat	45.5	143.01	342.85	164.28	380.21	2062.9	2202.5	1352.8
Barley	18.6	76.3	64.8	61.3	13.0	220.4	118.1	336.6
Maize	28.048	98.87	52.7	49.9	3.0	618.8	1718.2	67.2
Oats	0.4	0	0	0	5.5	0.4	30.9	0.6
Rye	0	0	28.0	10.2	7.8	0	10.0	2.5
Millet	0	0	0	0	0	0	0	3.10
Buckwheat	0	3.5	0	0	0	0	0	0
Peas	0	0	0	0	0	0	0	0.5
Sunflower	0	0	0	15.0	70.0	2.1	0	0.2
Ribbon grass	0	0	0	1.3	0	0	0	0
Brome grass	0	0	0	0	0	0	0	0
Peas	0	0	0	0	0	0	5.8	0
Soybeans	0	10.0	0	0	0	27.0	8.7	22.61
Spring vetch	0	6.0	0	0	0	0	0	0
Medicago	0	0	0	0	0	45.0	2.3	2.0
Sorghum	0	0	0	0	0	1.1	0	0.5
Sainfoin	0	0	0	0	0	2.5	0	0
Phalaris	0	0	0	0	0	0	0	169.75

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 A3.3.14 [12]:

$$E_{pollutant} = AR_{residues\_burnt} \times EF_{pollutant} \quad \text{(A3.3.14)}$$

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 A3.3.15 was used [12]:

$$AR_{residues\_burnt} = A \times M_B \times C_f \quad \text{(A3.3.15)}$$

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 A3.3.26) from the Ukrainian Scientific Research Institute of Civil Protection.

Table A3.3.26. 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
*Data of the Ukrainian Scientific Research Institute of Civil Protection corrected with analytical study		

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 2013 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 A3.3.27. 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.

Table A3.3.27. Activity data for HWP category calculations

	Sawnwood production, m^3	Wood panels production, m^3	Paper and paperboard production, m^3
1990	7 441 000	*1 893 235*	*874 099*
1991	6 106 000	*1 735 830*	*804 842*
1992	4 700 000	1 307 000	228 790
1993	3 882 000	1 036 000	145 290
1994	3 124 000	644 000	78 500
1995	2 917 000	596 000	85 200
1996	2 296 000	413 500	292 890
1997	2 306 000	398 800	264 000
1998	2 258 000	389 000	292 900
1999	2 141 000	434 000	310 900
2000	2 127 000	543 000	411 000
2001	1 995 000	726 000	479 900
2002	1 950 000	932 100	531 600
2003	2 197 000	1 045 000	618 037
2004	2 414 000	1 300 000	722 999
2005	2 409 000	1 509 000	768 010
2006	2 385 000	1 675 000	804 000
2007	2 525 000	2 029 000	937 001
2008	2 266 000	2 029 000	937 001
2009	1 753 000	1 578 000	813 999
2010	1 736 000	1 828 000	857 001
2011	1 888 000	2 081 700	986 998
2012	1 823 000	2 207 290	1 123 060
2013	1 804 000	2 277 690	1 079 350
2014	1 781 000	2 327 690	1 079 350
2015	1 534 500	2 377 690	1 079 350
2016	1 739 600	2 377 690	1 079 350

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 1990-2016. 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 1900-2016

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
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

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	MSW of it: official*	MSW of it: unofficial**	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
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
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

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
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
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

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
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	–	–	–	–	11924.52	11828.29	10752.99	1075.30	96.23	4473.25	4633.99	2817.28
2015	–	–	–	–	11580.35	11354.29	10322.08	1032.21	226.07	4293.98	4581.98	2704.38
2016	–	–	–	–	13524.79	13484.39	12258.54	1225.85	40.39	5099.55	5213.50	3211.74

* – 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 1990-2016

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 CO2-eq.	Methane emissions from MSW dumping, kt CO2-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	1474.17
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	1552.66
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	1569.49
2015	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.698	293.10	8141.32	1862.85	4612.29	1666.17
2016	13.7	3.9	31.8	1.8	3.6	1.4	1.9	41.9	13.73	0.697	193.98	8231.30	1856.96	4564.49	1809.85

*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 Energy balance of Ukraine in 2016 (th. tonnes of oil eq.)

DELIVERY AND CONSUMPTION	Coal and peat	Crude oil	Petroleum products	Natural gas	Nuclear energy	Hydropower	Energy of wind, sun	Biofuels and waste	Electric power	Heat	Total
Production	20146	2304	-	15172	21247	660	124	3348	-	599	63600
Import	10617	527	9155	8807	-	-	-	38	7	-	29151
Export	-495	-25	-24	-	-	-	-	-553	-329	-	-1427
International bunkering	-	-	-157	-	-	-	-	-	-	-	-157
Changes in inventories	-541	-	-586	1619	-	-	-	-1	-	-	491
Total primary energy supply	**29727**	**2806**	**8387**	**25598**	**21247**	**660**	**124**	**2832**	**-323**	**599**	**91658**
Transfers	-	293	-278	-	-	-	-	-	-	-	15
Statistical divergences	-	-121	-94	-181	-	-	-	-	-538[2]	-65	-999
Power plants	-14700	-	-65	-99	-21096	-660	-124	-5	12644	-59	-24164
Combined heat and power (CHP)	-2077	-	-541	-3278	-151	-	-	-255	1369	3237	-1697
Heating plants	-1553	-	-930	-5002	-	-	-	-557	-	6851	-1191
Coke enterprises (blast furnaces)	-3666	-	-	-	-	-	-	-	-	-	-3666
Gas companies	-34	-	-	-	-	-	-	-	-	-	-34
Enterprises manufacturing briquettes	167	-	-	-	-	-	-	-	-	-	167
Oil refineries	-	-2960	3200	-	-	-	-	-	-	-	240
Petrochemical companies	-	-	-	-	-	-	-	-	-	-	-
Other processing enterprises	-137	-	-	-	-	-	-	-291	-	-	-428
Own consumption within the energy sector	-964	-5	-48	-897	-	-	-	-	-1623	-1332	-4869
Losses at transportation and distribution	-456	-7	-1	-471	-	-	-	-	-1430	-1022	-3387
Final consumption	**6306**	**6**	**9630**	**15670**	**-**	**-**	**-**	**1724**	**10100**	**8209**	**51645**
Industry	**5376**	**-**	**176**	**2481**	**-**	**-**	**-**	**51**	**4295**	**2575**	**14955**
Ferrous metallurgy	4682	-	53	1186	-	-	-	14	1797	533	8265
Chemical and petrochemical	2	-	2	205	-	-	-	-	255	544	1008
Non-ferrous metals	96	-	1	129	-	-	-	-	127	243	596
Non-metal mineral products	573	-	14	363	-	-	-	3	192	58	1202

DELIVERY AND CONSUMPTION	Coal and peat	Crude oil	Petroleum products	Natural gas	Nuclear energy	Hydropower	Energy of wind, sun	Biofuels and waste	Electric power	Heat	Total
Transportation equipment	-	-	6	15	-	-	-	-	61	41	124
Machine engineering	1	-	4	101	-	-	-	2	211	92	410
Mining (excluding fuel)	1	-	26	286	-	-	-	-	818	92	1224
Food and tobacco	20	-	18	152	-	-	-	9	362	714	1276
Pulp and paper, printing	-	-	1	18	-	-	-	-	76	118	214
Wood processing and wood products	-	-	4	3	-	-	-	21	48	86	162
Construction	1	-	43	10	-	-	-	1	70	11	136
Textile and leather	-	-	1	5	-	-	-	-	26	16	49
Other industries	-	-	2	8	-	-	-	1	252	28	290
Transport	**6**	**-**	**7139**	**1399**	**-**	**-**	**-**	**37**	**584**	**-**	**9165**
Domestic air transporta-tion	-	-	-	-	-	-	-	-	-	-	-
Automobile	-	-	6975	28	-	-	-	37	-	-	7040
Railway	4	-	109	-	-	-	-	-	488	-	601
Pipeline	-	-	6	1369	-	-	-	-	35	-	1410
Inland navigation	-	-	48	-	-	-	-	-	-	-	48
Other types of transport	2	-	1	2	-	-	-	-	61	-	66
Other	**439**	**-**	**1679**	**10007**	**-**	**-**	**-**	**1635**	**5220**	**5634**	**24616**
Household sector	274	-	115	9285	-	-	-	1506	3089	3317	17586
Trade and services	157	-	105	584	-	-	-	109	1828	2073	4856
Agriculture	8	-	1427	139	-	-	-	20	302	244	2139
Fishing	-	-	2	-	-	-	-	-	2	-	4
Other consumers	-	-	31	-	-	-	-	-	-	-	31
Non-energy use	**485**	**6**	**636**	**1783**	**-**	**-**	**-**	**-**	**-**	**-**	**2910**
Industrial and energy sec-tor, conversion sector	485	6	522	1783	-	-	-	-	-	-	2796
including: feedstock for industries	-	-	90	1711	-	-	-	-	-	-	1801
On transport	-	-	12	-	-	-	-	-	-	-	12
In other sectors	-	-	102	-	-	-	-	-	-	-	102

1 Not accounting for the temporarily occupied territory of the Autonomous Republic of Crimea, Sevastopol, and part of the Anti-Terrorist Operation area.
2 The data include volumes of energy distributed to the temporarily occupied territory of the Autonomous Republic of Crimea, Sevastopol, and part of the Anti-Terrorist Opera-tion area.

A4.2 Balance of natural gas

Column	Balance sheet item	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Visible (balance) consumption, total, including:	mln. m3	70258.44	66736.31	52066.27	57757.35	62951.47	52667.55	48527.09	43285.34	38008.41	36281
2	- production	mln. m3	21103.63	21444.15	21504.85	20521.43	19886.50	19739.40	20554.20	21322.30*	20765.02*	21741*
3	- imports	mln. m3	53679.67	49187.85	26948.55	35799.24	43061.13	32926.96	27972.04	20265.95*	15584.89*	13942*
4	- stocks change	mln. m3	4524.86	3895.69	-3612.87	-1436.68	-3.84	-1.19	-0.85	-1697.09	-1658.50	-598
5	Actual consumption, total, including:	mln. m3	66879.59	63692.38	50495.62	55890.30	57761.95	53492.99	49403.87	41267.56	35135.06	34153
6	- Stationary Combustion**	mln. m3	55347.32	52293.36	42668.89	47382.68	47689.10	44766.26	41674.74	35845.71*	30408.21*	29499*
7	- Mobile Combustion**	mln. m3	4245.00	4471.03	3020.31	2631.04	2643.43	1818.88	1992.33	1398.37*	1145.11*	1400*
8	- Non-energy use**	mln. m3	284.96	297.30	269.34	232.49	595.54	577.64	403.15	171.41	174.87	494
9	- Category 2.B.1 Ammonia Production**	mln. m3	5627.31	5412.83	3530.10	4724.47	5876.51	5661.05	4677.67	3225.98	2779.87	2153
10	- Natural Gas Leaks**	mln. m3	1375.00	1217.86	1006.98	919.62	957.37	669.16	655.98	626.09	627.01	607
The difference between the balance sheet and actual consumption		mln. m3	3378,85	3043.93	1570.65	1867.05	5189.52	-825.44	-876.78	2017.78	2873.34	2128
		%	4,81%	4.56%	3.02%	3.23%	8.24%	-1.57%	-1.81%	4.66%	7.56%	5.9%
Data of the International Energy Agency (IEA, 2016)												
11	Domestic consumption of natural gas. observational	mln. m3	68746	64862	50622	56724	58401	53452	49488	41027	33120	32962
Comparison with the IEA data												
The difference between graphs 11 and 1		mln. m3	1512.44	1874.31	1444.27	1033.35	4550.47	-784.45	-960.91	-2258.34	-4888.41	-3319
		%	2.15%	2.81%	2.77%	1.79%	7.23%	-1.49%	-1.98%	-5.22%	-12.86%	-9.14%
The difference between graphs 11 and 5		mln. m3	-1866.41	-1169.62	-126.38	-833.70	-639.05	40.99	-84.13	-240.56	-2015.06	-1191
		%	-2.71%	-1.80%	-0.25%	-1.47%	-1.09%	0.08%	-0.17%	-0.59%	-6.08%	-3.49%

*in view of analytical study [26]

** Determined for standard conditions (20°C, 101.3 kPa)

A4.3 Coal Balance

Col-umn	Balance sheet item	Unit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Visible consumption (according to national statistics), including	kt	68209.75	69206.11	61718.66	64977.17	67884.07	71571.50	71499.99	58930.96	52938.26	55452
2	- mining	kt	58752.47	59500.23	55006.72	54957.14	62684.00	65522.60	64203.10	48866.74*	39673.20*	33985*
3	- imports	kt	13149.86	12805.17	7873.36	12145.05	12708.78	14764.24	14207.72	14694.16	14598.17	19778
4	- exports	kt	3621.15	4794.91	5290.01	6193.02	6990.34	6113.96	8537.28	7033.94	563.11	636
5	- stocks change	kt	71.43	-1695.62	-4128.59	-4068.00	518.37	2601.38	-1626.45	-2404.00	770.00	-2324
6	Actual consumption, total, in-cluding:	kt	72511.76	72433.42	64813.77	69714.70	74659.24	75660.98	74043.46	60182.05	48451.38	56705
7	- Stationary Combustion	kt	40443.83	41058.30	36811.87	39978.98	44689.82	47064.28	47271.03	41602.00*	35848.86*	37456*
8	- Used by coke production enter-prises	kt	28882.93	27723.05	24767.76	26369.38	27480.15	26330.36	24154.64	17020.00	11898.00	19083
9	- Non-energy use and losses	kt	3185.00	3652.07	3234.14	3366.34	2489.27	2266.34	2617.79	1560.05	704.53	166
The difference between the balance sheet and actual consumption		kt	-4302,01	-3227.31	-3095.11	-4737.53	-6775.17	-4089.48	-2543.47	-1251.09	4486.88	-1253
		%	-6,31%	-4.66%	-5.01%	-7.29%	-9.98%	-5.71%	-3.56%	-2.12%	8.48%	-2,26%
Data of the International Energy Agency (IEA, 2016)												
11	Gross total coal consumption (IEA annual questionnaire)	kt	71317	70361	61377	66095	72929	73586	71396	60572	45285	49862
12	Gross consumption of coal for coking (IEA annual questionnaire)	kt	28883	27722	24771	26369	27487	27009	24165	17020	11898	14292
13	Gross consumption of coal with-out coking coal (IEA annual questionnaire)	kt	42434	42639	36606	39726	45442	46577	47231	43442	33387	35570
Comparison with the IEA data												
The difference between graphs 11 and 1		kt	3107.25	1154.89	-341.66	1117.83	5044.93	2014.50	-103.99	1641.04	-7653.26	-5590
		%	4.36%	1.64%	-0.56%	1.69%	6.92%	2.74%	-0.15%	2.71%	-16.90%	-10,08%
The difference between graphs 11 and 6		kt	-1194.76	-2072.42	-3436.77	-3619.70	-1730.24	-2074.98	-2647.46	389.95	-3166.38	-6843
		%	-1.68%	-2.95%	-5.60%	-5.48%	-2.37%	-2.82%	-3.71%	0.64%	-6.99%	-12,07%
The difference between graphs 12 and 8		kt	0.07	-1.05	3.24	-0.38	6.85	678.64	10.36	0.00	0.00	- 4791
		%	0.00%	0.00%	0.01%	0.00%	0.02%	2.51%	0.04%	0.00%	0.00%	25.1%

* in view of analytical study [26]

A4.4 The coking coal, coke, and coke gas balance

Table A4.4.1 presents the balance of coal for coking in 2016 compiled on the basis of data on the production amount (finished hard coal for coking in accordance with statistical form 1-P [26]), 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 A4.4.1. The balance of apparent consumption of coal for coking in 2016

	Production (extraction)	Import	Export	Stocks change	Total consumption
Amount, kt	6508.8	12359.9	559.6	-773.9	19083.0

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 17,174.7 kt.

The result of the cooking process is coke, coke oven gas, coal tars, and other products (Table A4.4.2).

Table A4.4.2. Yield of coke ovens in 2016, according to statistical form 1-P

Indicator	Coke, calculated as the dry weight, kt	Coke oven gas, mln. m3	Coal tars, calculated as the anhydrous state, kt	Other products (benzene, ammonium sulfate, etc.).
Amount	12722	1752	720	Not estimated
Yield by weight as dry-charge	74.08%	10.20%	4.19%	11.53%

* For conversion into units of weight, the density of coke oven gas is taken to be 0.475 kg/m^3

Table A4.4.3 presents the coke weight balance in 2016 (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 A4.4.3. Balance of coke in 2016, dry weight, kt

	Production	**Import**	**Export**	**Changes in inventories**	**Total consumption on the balance**	**Actual consumption**	**Discrepancy**
Amount	12722.0	1549.6	224.6	-160.3	14207.3	13204.1	7.6%
Data source	Form 1-P	Statistical data on exports/imports of products		Form 4-MTP	Estimated value	Form 4-MTP, enterprise data	Estimated value

Table A4.4.4 presents data on aggregated volumes of coke consumption by industries with an indication of the categories of the respective amounts of GHG emissions.

Table A4.4.4. Coke consumption in 2016, 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	13204.1	100.00%	
Consumption for iron production	12398.6	93.90%	2.C.1.2 Iron Production
Consumption for ferroalloys production	474.20	3.59%	2.C.2 Ferroalloys Production
Other consumption	331.30	2.51%	

Table A4.4.5 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 A4.4.5. Coke oven gas production and consumption in 2016, according to statistical reporting, and its accounting by CRF categories

Indicator	Index value, mln. m3	Index value, %	CFR category of the GHG emissions
Consumption of coke oven gas for stationary combustion in coke batteries, boilers of enterprises, etc.	3684	98.4	1.A Stationary Combustion, including: 1.A.1.a – 852 mln m3; 1.A.1.c – 840 mln m3; 1.A.2.a – 1896 mln m3; 1.A.2.e – 13 mln m3; 1.A.2.f – 17 mln m3; 1.A.2.g – 67 mln m3;
Losses due to non-use, no account, and for other reasons	60	1.6	1.B.1.b - Flaring

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 3712 thd. m3, which is 2.47 % lower than the amount of its production (3805,9 thd). This discrepancy is due to the fact that 2016 is characterized by significant losses of coke oven gas as a consequence of the major destruction of the industrial infrastructure in Donetsk and Luhansk regions, which for obvious reasons could not be reflected in the departmental energy reporting.

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 Abcent 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.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.AB	Fuel Combustion - Reference Approach / Solid Fuels / Anthracite, Coking Coal	IE	Emissions are accounted in 1.AB (Other Bituminous Coal)
		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.AD	Feedstocks, reductants and other non-energy use of fuels / Liquid fossil / 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 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.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.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
	N_2O	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.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
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
	N_2O	2.B.1	Ammonia Production	NE	No IPCC Metodology provided
AGRICULTURE	N_2O	3.B.2.5	Indirect N_2O Emissions	NE	There are no country specific factors for 2006 IPCC methodology application
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	IE	CO_2 emissions from drained organic soils are included into CSC

			and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils		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	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	NE	IPCC 2006 consider CH_4 emissions to be negligible
		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.1.2.a	Municipal Solid Waste	IE	Included in 5.C.1.1.a Municipal Solid Waste. For estimation of methan and nitrous oxide emission from waste inseneration the separation of waste into biogenic and non-biogenic (fossil) was not conducted
		5.C.1.2.b	Other (please specify)/ Clinical Waste	IE	Included in 5.C.1.1.b Other (please specify) Clinical Waste. For estimation of methan and nitrous oxide emission from waste inseneration the separation of waste into biogenic and non-biogenic (fossil) was not conducted

		5.C.1.2.b	Other (please specify)/ Industrial Solid Wastes	IE	Included in 5.C.1.1.b Other (please specify) Industrial Solid Wastes. For estimation of methan and nitrous oxide emission from waste inseneration the separation of waste into biogenic and non-biogenic (fossil) was not conducted
		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.1.2.a	Municipal Solid Waste	IE	Included in 5.C.1.1.a Other (please specify) Municipal Solid Waste. For estimation of methan and nitrous oxide emission from waste inseneration the separation of waste into biogenic and non-biogenic (fossil) was not conducted
		5.C.1.2.b	Other (please specify)/ Clinical Waste	IE	Included in 5.C.1.1.b Other (please specify) Clinical Waste. For estimation of methan and nitrous oxide emission from waste inseneration the separation of waste into biogenic and non-biogenic (fossil) was not conducted
		5.C.1.2.b	Other (please specify)/ Industrial Solid Wastes	IE	Included in 5.C.1.1.b Other (please specify) Industrial Solid Wastes. For estimation of methan and nitrous oxide emission from waste inseneration the separation of waste into biogenic and non-biogenic (fossil) was not conducted
		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

A5.2 KP-LULUCF inventory

Table A5.2 shows detailed information about the KP-LULUCF categories, where notation keys were used (NE, IE).

Table A5.2 Absent sources / sinks in the GHG inventory for activities under paragraphs 3 and 4 of Article 3 KP

Gas	Category source		Activity under article	Notation Key	The reason for the use in the NIR
CO_2	NIR-1	Afforestation and Reforestation	3.3 KP	IE	CSC in HWP pool is reported under FM activity
CO_2	KP.A.1	Afforestation and Reforestation	3.3 KP	IE	Carbon losses of below-ground living biomass from cuttings are included into above-ground living biomass losses
CO_2	KP.B.1	Forest Management	3.4 KP	IE	CO_2 emissions are included in losses of above-ground bio-mass

ANNEX 6 SUPPLEMENTARY INFORMATION PRESENTED AS PART OF ANNUAL SUBMISSION AND THE INFORMATION REQUIRED IN ACCORDANCE WITH PARAGRAPH 1, ARTICLE 7 OF THE KYOTO PROTOCOL, AND OTHER APPLICABLE INFORMATION

A6.1 Annual submission of the National Inventory Report

A6.1.1 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-Departmental Commission to Implement the UN Framework Convention on Climate Change" of 14.04.1999 No.583	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	http://zakon.nau.ua/doc/?uid=1093.1048.0
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	Order of the National Environmental Investment Agency of Ukraine "Procedure for the National Inventory of Anthropogenic Greenhouse Gas Emissions by Sources and Sinks" of 24.10.2008, No. 58	http://www.carbonunitsregistry.gov.ua/ua/publication/content/669.htm
12	Resolution of the Cabinet of Ministers of Ukraine "On Optimization of the System of Central Executive Authorities" of 10.10.2014, No. 442	http://zakon3.rada.gov.ua/laws/show/442-2014-%D0%BF
13	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	http://zakon4.rada.gov.ua/laws/show/32-2015-п
14	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	http://zakon2.rada.gov.ua/laws/show/616-2015-п

A6.1.2 Order of the Ministry of Environmental Protection No.268 of May 31, 2007

Order of the Ministry of Environmental Protection No. 268 of May 31, 2007 approving the Work Plan for Annual Preparation and Maintenance of the National Inventory of Greenhouse Gas Emissions and Sinks and the Work Plan to Maintain and Control the Quality of Input Data and Calculations for the Annual Preparation of the National Inventory Report of Emissions and Sinks of Greenhouse Gases

Pursuant to the Procedure for the National System for Estimation of Anthropogenic Emissions and Sinks of Greenhouse Gases not Regulated under Montreal Protocol on Ozone Layer Depleting Substances approved with Resolution of the Cabinet of Ministers of Ukraine of 21.04.06 No. 554 and to meet requirements of the UN Framework Convention on Climate Change, Kyoto Protocol to it, and Decisions of the Conference of the Parties to the UN Framework Convention on Climate Change/Meeting of the Parties to the Kyoto Protocol

I ORDER:

1. To adopt the attached:

The Action Plan on annual preparation and maintenance of the Annual National Inventory of emissions and sinks of greenhouse gases;

The Action Plan for quality assurance and control for raw data and calculation within the annual preparation of the National Inventory of emissions and sinks of greenhouse gases.

2. Control over execution of the Order shall be exerted by First Deputy Minister S. Kurulenko

Deputy Minister S. Hlazunov

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.

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	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	101627.80	1.85	3.59	4.04	1.63	0.00	0.11	0.01	0.30	0.09
		CH_4	184.29	86.91	1.85	83.53	83.55	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	635.15	389.68	1.85	415.73	415.73	0.25	0.00	0.00	0.07	0.00	0.01
1.A.2	Manufacturing Industries and Construction	CO_2	111029.98	17853.43	3.24	5.01	5.97	0.11	-0.03	0.02	-0.13	0.09	0.02
		CH_4	80.76	27.07	3.24	120.59	120.64	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	144.29	45.72	3.24	416.53	416.54	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport	CO_2	107066.83	31001.25	10.33	4.57	11.30	1.19	-0.01	0.03	-0.04	0.51	0.26
		CH_4	703.21	194.89	10.33	15.39	18.54	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4022.81	1010.42	10.33	10.94	15.05	0.00	0.00	0.00	-0.01	0.02	0.00
1.A.4	Other Sectors	CO_2	98704.92	27348.48	6.57	7.21	9.75	0.69	-0.01	0.03	-0.07	0.29	0.09
		CH_4	3009.05	314.77	6.57	90.80	91.04	0.01	0.00	0.00	-0.08	0.00	0.01
		N_2O	296.63	43.12	6.57	305.91	305.98	0.00	0.00	0.00	-0.02	0.00	0.00
1.A.5	Other (Not specified else-where)	CO_2	105.56	527.92	5.00	2.00	5.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	0.11	0.54	5.00	150.00	150.08	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	0.26	1.30	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	276.20	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	61923.39	16347.07	9.20	5.00	10.47	0.28	-0.01	0.02	-0.03	0.24	0.06
1.B.2	Oil and Natural Gas and Other Emissions from Energy Pro-duction	CO_2	3023.81	2096.78	2.92	7.92	8.44	0.00	0.00	0.00	0.01	0.01	0.00
		CH_4	62065.54	27237.53	6.34	22.61	23.48	3.96	0.01	0.03	0.12	0.27	0.09

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	3.61	0.98	3.74	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	3622.85	1.90	5.41	5.73	0.00	0.00	0.00	0.00	0.01	0.00
2.A.2	Lime Production	CO_2	5121.81	2472.21	12.03	16.06	20.07	0.02	0.00	0.00	0.01	0.05	0.00
2.A.3	Glass Production	CO_2	173.23	227.91	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	67.89	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	298.81	8.41	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	9402.92	2662.89	5.39	7.00	8.83	0.01	0.00	0.00	-0.01	0.02	0.00
2.B.2	Nitric Acid Production	N_2O	5284.58	1877.17	2.00	5.00	5.39	0.00	0.00	0.00	0.00	0.01	0.00
2.B.5	Carbide Production	CO_2	122.08	32.55	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	3.77	3.57	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	189.95	5.00	15.00	15.81	0.00	0.00	0.00	0.00	0.00	0.00
2.B.8	Petrochemical and Carbon Black Production	CO_2	1962.33	188.88	0.00	3.39	3.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	256.76	51.73	0.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C.1	Iron and Steel Production	CO_2	79689.69	42989.72	2.02	2.54	3.25	0.19	0.02	0.05	0.04	0.14	0.02
		CH_4	1117.49	590.26	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	1848.51	7.07	5.00	8.66	0.00	0.00	0.00	0.00	0.02	0.00
		CH_4	15.11	1.26	5.00	25.00	25.50	0.00	0.00	0.00	0.00	0.00	0.00
2.C.3	Aluminium Production	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	19.09	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	1.13	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	114.91	6.00	50.09	50.45	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	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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.D.2	Paraffin Wax Use	CO_2	122.84	10.31	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	—	889.00	54.32	35.53	64.91	0.03	0.00	0.00	0.04	0.08	0.01
2.G.1	Electrical Equipment	SF_6	0.01	24.11	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	145.26	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	45924.87	10752.01	6.00	7.73	9.78	0.11	-0.01	0.01	-0.05	0.10	0.01
3.B.1	Manure management / CH_4 Emissions	CH_4	3747.21	1057.66	6.00	13.06	14.38	0.00	0.00	0.00	0.00	0.01	0.00
3.B.2	Manure management / N_2O and NMVOC Emissions	N_2O	3561.23	1068.77	6.00	50.00	50.36	0.03	0.00	0.00	-0.01	0.01	0.00
3.C	Rice cultivation	CH_4	216.43	89.07	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	30549.23	24878.27	6.00	93.57	93.77	52.72	0.02	0.03	1.46	0.24	2.18
3.D.2	Indirect N_2O Emissions from managed soils	N_2O	5160.72	3997.98	6.00	95.50	95.69	1.42	0.00	0.00	0.23	0.04	0.05
3.G	Liming	CO_2	2592.08	140.09	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	457.62	6.00	50.00	50.36	0.01	0.00	0.00	0.02	0.00	0.00
4	**LAND USE, LAND-USE CHANGE AND FORESTRY**												
4.A	Forest Land	CO_2	-63405.76	-66332.25	6,00	17,00	18,03	13,85	-0,05	-0,07	-0,83	-0,63	1,09
		CH_4	7.95	3.61	15,00	37,90	40,76	0,00	0,00	0,00	0,00	0,00	0,00
		N_2O	52.86	56.52	15,00	22,98	27,44	0,00	0,00	0,00	0,00	0,00	0,00
4.B	Cropland	CO_2	-4642.34	47250.44	6,00	40,00	40,45	35,38	0,06	0,05	2,20	0,45	5,05
		CH_4	—	0.35	6,00	22,70	23,48	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	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	0.01	0.57	6,00	27,50	28,15	0,00	0,00	0,00	0,00	0,00	0,00
4.C	Grassland	CO_2	-947.20	-741.52	6,00	26,32	27,00	0,00	0,00	0,00	-0,01	-0,01	0,00
		CH_4	0.13	0.07	6,00	39,10	39,56	0,00	0,00	0,00	0,00	0,00	0,00
		N_2O	0.15	0.29	6,00	47,60	47,98	0,00	0,00	0,00	0,00	0,00	0,00
4.D	Wetlands	CO_2	11996.11	150.29	10,00	24,50	26,46	0,00	0,00	0,00	-0,12	0,00	0,01
		CH_4	3.26	0.58	10,00	27,20	28,98	0,00	0,00	0,00	0,00	0,00	0,00
		N_2O	27.06	7.50	10,00	36,70	38,04	0,00	0,00	0,00	0,00	0,00	0,00
4.E.2	Land converted to Settlements	CO_2	3.01	601.79	10,00	50,00	50,99	0,01	0,00	0,00	0,03	0,01	0,00
		N_2O	0.02	45.28	10,00	50,00	50,99	0,00	0,00	0,00	0,00	0,00	0,00
4.F.2	Land converted to Other Land	CO_2	1588.47	233.94	10,00	50,00	50,99	0,00	0,00	0,00	-0,02	0,00	0,00
		N_2O	135.21	19.92	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	-2789.59	707.96	13,00	26,80	29,79	0,00	0,00	0,00	0,05	0,01	0,00
5	**WASTE**												
5.A.	Solid Waste Disposal	CH_4	6534.85	8231.30	31.62	47.26	56.86	2.12	0.01	0.01	0.31	0.41	0.27
5.B.	Biological Treatment of Solid Waste	CH_4	18.14	18.31	30.56	100.00	104.57	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	16.22	16.37	30.56	100.00	104.57	0.00	0.00	0.00	0.00	0.00	0.00
5.C.	Incineration and Open Burn-ing of Waste	CO_2	30.92	8.98	31.03	25.98	40.47	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	0.60	0.21	31.03	100.00	104.70	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4.66	2.12	31.03	100.00	104.70	0.00	0.00	0.00	0.00	0.00	0.00
5.D.1	Domestic Wastewater	CH_4	2212.06	2124.09	18.03	36.88	41.05	0.07	0.00	0.00	0.05	0.06	0.01

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	1570.15	1040.05	36.23	62.50	72.24	0.05	0.00	0.00	0.03	0.06	0.00
5.D.2	Industrial Wastewater	CH_4	1416.29	861.10	22.85	40.91	46.86	0.02	0.00	0.00	0.02	0.03	0.00
		N_2O	119.94	62.54	22.85	50.00	54.97	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL		**888740.53**	**321283.38**				**114.20**					**9.35**
						Percentage uncertainty in total inventory		**10.69**				**Trend uncertainty**	**3.06**

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	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	101627.80	1.85	3.59	4.04	1.46	0.00	0.11	0.02	0.28	0.08
		CH_4	184.29	86.91	1.85	83.53	83.55	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	635.15	389.68	1.85	415.73	415.73	0.23	0.00	0.00	0.07	0.00	0.01
1.A.2	Manufacturing Industries and Construction	CO_2	111029.98	17853.43	3.24	5.01	5.97	0.10	-0.02	0.02	-0.12	0.09	0.02
		CH_4	80.76	27.07	3.24	120.59	120.64	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	144.29	45.72	3.24	416.53	416.54	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport	CO_2	107066.83	31001.25	10.33	4.57	11.30	1.07	-0.01	0.03	-0.04	0.48	0.23
		CH_4	703.21	194.89	10.33	15.39	18.54	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4022.81	1010.42	10.33	10.94	15.05	0.00	0.00	0.00	0.00	0.02	0.00
1.A.4	Other Sectors	CO_2	98704.92	27348.48	6.57	7.21	9.75	0.62	-0.01	0.03	-0.06	0.27	0.08
		CH_4	3009.05	314.77	6.57	90.80	91.04	0.01	0.00	0.00	-0.07	0.00	0.01
		N_2O	296.63	43.12	6.57	305.91	305.98	0.00	0.00	0.00	-0.02	0.00	0.00
1.A.5	Other (Not specified elsewhere)	CO_2	105.56	527.92	5.00	2.00	5.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	0.11	0.54	5.00	150.00	150.08	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	0.26	1.30	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	276.20	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	61923.39	16347.07	9.20	5.00	10.47	0.25	-0.01	0.02	-0.03	0.22	0.05
1.B.2	Oil and Natural Gas and Other Emissions from Energy Production	CO_2	3023.81	2096.78	2.92	7.92	8.44	0.00	0.00	0.00	0.01	0.01	0.00

IPCC category		Gas	Base 1990 year emissions or removals, kt CO_2 equivalent	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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
		CH_4	62065.54	27237.53	6.34	22.61	23.48	3.55	0.01	0.03	0.12	0.26	0.08
		N_2O	2.33	1.06	3.61	0.98	3.74	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	3622.85	1.70	5.48	5.73	0.00	0.00	0.00	0.00	0.01	0.00
2.A.2	Lime Production	CO_2	5121.81	2472.21	12.00	16.09	20.07	0.02	0.00	0.00	0.01	0.04	0.00
2.A.3	Glass Production	CO_2	173.23	227.91	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	67.89	2.00	6.00	6.32	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4.b	Other uses of Soda Ash	CO_2	298.81	8.41	5.00	7.00	8.60	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO_2	9402.92	2662.89	5.39	7.00	8.83	0.00	0.00	0.00	-0.01	0.02	0.00
2.B.2	Nitric Acid Production	N_2O	5284.58	1877.17	5.00	2.00	5.39	0.00	0.00	0.00	0.00	0.01	0.00
2.B.5	Carbide Production	CO_2	122.08	32.55	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	3.77	3.57	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	189.95	5.00	15.00	15.81	0.00	0.00	0.00	0.00	0.00	0.00
2.B.8	Petrochemical and Carbon Black Production	CO_2	1962.33	188.88	0.00	3.39	3.39	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	256.76	51.73	0.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
2.C.1	Iron and Steel Production	CO_2	79689.69	42989.72	2.05	2.58	3.29	0.17	0.02	0.05	0.04	0.13	0.02
		CH_4	1117.49	590.26	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	1848.51	7.07	5.00	8.66	0.00	0.00	0.00	0.00	0.02	0.00
		CH_4	15.11	1.26	5.00	25.00	25.50	0.00	0.00	0.00	0.00	0.00	0.00
2.C.3	Aluminium Production	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	19.09	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	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	1.13	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	114.91	6.00	50.09	50.45	0.00	0.00	0.00	0.00	0.00	0.00
2.D.2	Paraffin Wax Use	CO_2	122.84	10.31	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 Sub-stances	HFCs	—	889.00	54.32	35.53	64.91	0.03	0.00	0.00	0.03	0.07	0.01
2.G.1	Electrical Equipment	SF_6	0.01	24.11	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	145.26	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	45924.87	10752.01	6.00	7.73	9.78	0.10	-0.01	0.01	-0.05	0.10	0.01
3.B.1	Manure management / CH_4 Emissions	CH_4	3747.21	1057.66	6.00	13.06	14.38	0.00	0.00	0.00	0.00	0.01	0.00
3.B.2	Manure management / N_2O and NMVOC Emissions	N_2O	3561.23	1068.77	6.00	50.00	50.36	0.03	0.00	0.00	-0.01	0.01	0.00
3.C	Rice cultivation	CH_4	216.43	89.07	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	30549.23	24878.27	6.00	93.57	93.77	47.27	0.01	0.03	1.38	0.22	1.94
3.D.2	Indirect N_2O Emissions from managed soils	N_2O	5160.72	3997.98	6.00	95.50	95.69	1.27	0.00	0.00	0.22	0.04	0.05
3.G	Liming	CO_2	2592.08	140.09	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	457.62	6.00	50.00	50.36	0.00	0.00	0.00	0.02	0.00	0.00
5	**WASTE**												
5.A.	Solid Waste Disposal	CH_4	6534.85	8231.30	31.62	47.26	56.86	1.90	0.01	0.01	0.29	0.39	0.24
5.B.	Biological Treatment of Solid Waste	CH_4	18.14	18.31	30.56	100.00	104.57	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	2016 year emissions or removals, kt CO_2 equivalent	Activity data uncertainty, %	Emission factor / estimation parameter uncertainty, %	Combined uncertainty, %	Contribution to Variance by Category in 2016 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	16.22	16.37	30.56	100.00	104.57	0.00	0.00	0.00	0.00	0.00	0.00
5.C.	Incineration and Open Burning of Waste	CO_2	30.92	8.98	31.03	25.98	40.47	0.00	0.00	0.00	0.00	0.00	0.00
		CH_4	0.60	0.21	31.03	100.00	104.70	0.00	0.00	0.00	0.00	0.00	0.00
		N_2O	4.66	2.12	31.03	100.00	104.70	0.00	0.00	0.00	0.00	0.00	0.00
5.D.1	Domestic Wastewater	CH_4	2212.06	2124.09	18.03	36.88	41.05	0.07	0.00	0.00	0.05	0.06	0.01
		N_2O	1570.15	1040.05	36.23	62.50	72.24	0.05	0.00	0.00	0.03	0.06	0.00
5.D.2	Industrial Wastewater	CH_4	1416.29	861.10	22.85	40.91	46.86	0.01	0.00	0.00	0.02	0.03	0.00
		N_2O	119.94	62.54	22.85	50.00	54.97	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL		**946711.20**	**339278.05**				**58.24**					**2.83**
						Percentage uncertainty in total inventory		**7.63**				**Trend uncertainty**	**1.68**

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 2017 (ARR 17) in the NIR

Report of the individual review of the inventory submission of Ukraine submitted in 2017 has not been published at a time of current NIR development. Comments on previous ARR is contained in NIR submitted in 2017.

A8.2 Improvement Plan for the NIR

Ukraine recognizes the high importance of data collection for land representation to fully meet requirements of UNFCCC and Kyoto Protocol reporting. The Ministry of Ecology and Natural Resources of Ukraine (MENR) is considering the work currently ongoing in Ukraine in the field of land cover identification and traction.

According the content and recommendations from review of the inventory submission of Ukraine submitted in 2015 (ARR 15) Party planned significantly improve spatial component of the national inventory system by next directions: (a) Organizational and structural improvement, (b) expanding of sources of information, (c) use of modern methods and methodologies of information processing , (d) experimental steps to verify the transition to new technologies

(a) Organizational and structural improvement,

The Party planned to include in its national inventory system three high professional organizations:

1) Space Research Institute NAS Ukraine and SSA Ukraine for satellite image data receiving and processing, (According Memorandum of Cooperation)

2) The State Land Cadastre ofState Service of Ukraine for Geodesy, Cartography and Cadastrefor digital data receiving and processing

3) World Data Center for Geoinformatics and Sustainable Development for additional data for QA/QC for spatial information

First step of this improvement was made by

(b) **Expanding of sources of information**

The Party planned to notably expand the spectrum of sources of information: to include information from different Ukrainian and international organizations, different sentinels (including multispectral sentinels), different open information systems

(c) **Use of modern methods and methodologies of information processing**

The Party planned to start use the modern technologies (geographic information systems, spatial analysis, including satellite image interpretation (including Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), Vegetation Productivity Index (VPI), Vegetation Condition Index (VCI). CORINE Land Cover is planned to be introducedwith the CORINELand Cover methodology used by Ireland and Portugal for LULUCF reporting

Taking into account the recommendations of the ERT contained in the ARR 2015, 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.AA Fuel Combustion Sectoral Approach, 1.AB Fuel Combustion Reference Approach	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	2018-2019	Application for funding is under consideration	
	1.A.3.b Road Transport	Verification of motor fuels consumption volumes by transport sector within the context of annual preparation of the Ukraine's Greenhouse Gas Inventory	2018-2019	Application for funding is under consideration	
	1.A.3.b Road Transport	Estimation of GHG emissions from liquid biomass consumption in transport sector of Ukraine	2018-2019	Funding is envisaged from different sources including international technical assistance	
	1.A.3.b Road Transport	Estimation of GHG emissions from transport sector in Ukraine	2018-2019	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	2018-2019	Funding is envisaged from different sources including international technical assistance	
	1.A Fuel Combustion	Development of methods and tools for accounting of greenhouse gas emissions from energy use of biomass in Ukraine	2018-2019	Funding is envisaged from different sources including international technical assistance	
	1.A Fuel Combustion	Development of the method to account for greenhouse gas emissions from lubricants use in Ukraine	2018-2019	Funding is envisaged from different sources including international technical assistance	
Industrial Processes and Product Use	2.B.2 Nitric Acid Production	Development of methodological guidelines on determination of greenhouse gas emissions at chemical enterprises for nitric and adipic acid production	2017 - 2019	Taken for consideration to amend the activity plan of the Ministry of Ecology and Natural Resources of Ukraine. It is expected to attract financing.	
	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	2017 - 2019	Taken for consideration to amend the activity plan of the Ministry of Ecology and Natural Resources of Ukraine. 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.	2017 - 2019	Taken for consideration to amend the activity plan of the Ministry of Ecology and Natural Resources of Ukraine. It is expected to attract financing.	

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
Agriculture	3.B Manure Management	Development of method for estimation of the amount of volatile solid excretion in the composition of animal manure	2018-2019	Funding is envisaged from different sources including international technical assistance	
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	2018-2019	Funding is envisaged from different sources including international technical assistance	
	4.A Forest land	Filling the database of plots by activities under paragraphs 3 and 4, Article 3 of the Kyoto Protocol	2018-2019	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	2018-2019	Funding is envisaged from different sources including international technical assistance	
	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	2018-2019	Funding is envisaged from different sources including international technical assistance	
	4.A Forest land 4.B Cropland 4.C Grassland 4.D Wetlands	Analysis of organic soil use on different land-uses in Ukraine since 1990	2018-2019	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	2018-2019	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	Definition of Flooded land category taking into consideration national definitions. Classification of land-use changes into flooded lands category for entire time series since 1990	2018-2019	Funding is envisaged from different sources including international technical assistance	
Waste	5.A Solid Waste Disposal	Investigation of the MSW composition in Ukraine	2018-2019	Funding is envisaged from different sources including international technical assistance	
	5.A Solid Waste Disposal	Development of methodical guidelines to account for greenhouse gas emissions from industrial waste disposal in Ukraine	2018-2019	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
	5.C Incineration and Open Burning of Waste	Development of methodical guidelines to account for greenhouse gas emissions from waste incineration in Ukraine	2018-2019	Funding is envisaged from different sources including international technical assistance	
	5.B Biological Treatment of Solid Waste	Development of methodical guidelines to account for greenhouse gas emissions from biological treatment of waste in Ukraine	2018-2019	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 CO2 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. The opportunities of involving international technical assistance to continue filling in the database of plots by activities reported on under paragraphs 3 and 4, Article 3 of the Kyoto Protocol.