Part 7

DOCUMENTATION FOR THE PURPOSES OF THE TRANSBOUNDARY IMPACT ASSESSMENT PROCEDURE

for the Project involving the construction and operation of the First Nuclear Power Plant in Poland with a capacity of up to 3,750 MWe, in the territory of the following communes: Choczewo, or Gniewino and Krokowa

Extract from Volume V of the EIA Report – Summary – Assessment Results and Conclusions

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świadomie o atomie
energia jądrowa w Polsce

Polskie Elektrownie Jądrowe sp. z o.o.

Glossary

Term/Abbreviation	Definition
AHP	Analytical hierarchical process
ALARA	An optimisation principle in radiological protection, according to which the exposure to ionising radiation should be reduced to a level that is *as low as reasonably achievable*
ALARP	Principle of radiological protection – as low as reasonably practicable
BAT	Best available techniques/technology
BIOZ	Health, Safety and Environmental plan (*Plan bezpieczeństwa i ochrony zdrowia*) drawn up in compliance with the Building Law Act of 7 July 1994
CEZAR	Radiation Emergency Centre
AP1000 Plant Vendor	Westinghouse Electric Company
The Habitats Directive	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild flora and fauna
NPP/ Nuclear Power Plant	The First Polish Nuclear Power Plant comprising three nuclear power units with AP1000 reactors with a total capacity of up to 3,750 MWe, in the territory of the following communes: Choczewo, or Gniewino and Krokowa
Nuclear power plant	Nuclear facility within the meaning of the Atomic Law Act of 29 November 2000
EP-K	Energoprojekt-Katowice
EPS	European protected species
EP-W	Energoprojekt-Warszawa
FRRS	Fish Recovery and Return System
GIOŚ	Chief Inspectorate for Environmental Protection
GIS	Geographical Information System
GDOŚ	General Director for Environmental Protection
HRA	Habitat regulations assessment
ICRP	International Commission on Radiological Protection, founded in Sweden
IMGW-PIB	Institute of Meteorology and Water Management – National Research Institute
SWB	Surface water bodies
JNCC	Joint Nature Conservation Committee
IAEA	International Atomic Energy Agency
PAA	President of the National Atomic Energy Agency/ National Atomic Energy Agency
EIA Act	Act of 3 October 2008 on providing access to information about the environment and its protection, participation of the public in environmental protection and assessments of the environmental impact
Project	Construction and operation of the First Polish Nuclear Power Plant with a capacity of up to 3,750 MWe, in the territory of the following communes: Choczewo, or Gniewino and Krokowa
Atomic Law Act	Act of 29 November 2000 Atomic Law
MOLF	Marine off-loading facility

Term/Abbreviation	Definition
MTZ	Marine traffic zone of approximately 1 km in width, established for the purposes of the Project
NCBJ	National Centre for Nuclear Research
NRC	US Nuclear Regulatory Commission
ONR	UK Office for Nuclear Regulation
RUA	Restricted Use Area
PWR	Pressurised Water Reactor
Decision/GDOŚ Decision/Scoping Decision	Decision of the General Director for Environmental Protection dated 25 May 2016 (DOOŚ-OA.4205.1.2015.23) defining the scope of the environmental impact report for the project involving the construction and operation of the first Nuclear Power Plant in Poland with a capacity of up to 3750 MWe in the territory of the following communes: Choczewo, or Gniewino and Krokowa
EIA Report	Report on the environmental impact of the project involving the construction and operation of the first Nuclear Power Plant in Poland with a capacity of up to 3 750 MWe, in the territory of the following communes: Choczewo, or Gniewino and Krokowa
RCS	Reactor coolant system
MSFD	Marine Strategy Framework Directive – Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy
WFD	Water Framework Directive – Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
RODOS	Real-time Online Decision Support System for nuclear emergency management
Siting Regulation	Regulation of the Council of Ministers of 10 August 2012 on the detailed scope of site characterisation for land intended to host a nuclear facility, instances for excluding any given site from the possibility to host a nuclear facility, and on requirements concerning the siting report for a nuclear facility
SEP	Construction stakeholder engagement plan
ANN	Artificial neural networks
VFS	Containment air filtration system
WWS	Waste water system
WLS	Liquid radwaste system
Designated Project Areas	Areas in which the Nuclear Power plant is planned to be sited in both site variants, identical with the Project Area

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Introduction

Volume V is a summary of all the analyses carried out and the results presented in the EIA Report, which are supplemented by some specific issues complementing the overall assessment of the effects of the Project (in all its phases) on the environment and human health.

The first chapter of this Volume [Chapter V.1] presents a description of the forecasting methods used in the EIA Report, on the basis of which analyses of the impact of the NPP on the environment and human health and life were carried out. With regard to significant negative impacts of the NPP on the environment, mitigating activities/measures were designed, the use of which would make it possible to prevent or reduce the impacts of the Project during the construction and operational phases. A proposal of the scope of activities that have to be carried out in order to minimise the environmental impact of the Project is presented in [Chapter V.3]

The key issue in the EIA Report is a multi-criteria analysis, which could be performed only after the assessment of the forecasted impacts of the Project in the considered site variants and its sub-variants. [Chapter V.2] presents the methodology of the applied multi-criteria analysis together with its results, i.e. the variant proposed by the Investor for implementation, the rational variant most beneficial for the environment and the rational alternative variant together with reasons for its selection.

[Chapter V.4] presents methodologies and results of the transboundary impact, which should be considered in the context of possible direct impact on areas situated outside Poland's borders, i.e. the territories of the countries bordering on Poland, as well as countries that do not share a common border but are located close enough to be taken into account in the analyses.

[Chapter V.5] describes the methodology on the basis of which the authors of the EIA Report identified the types, places, extent of social conflicts and social groups in which these conflicts occur and may potentially occur. In addition, the importance of social conflicts and the risks associated with them were determined and an analysis was carried out on this basis, along with an indication of activities, tools for its mitigation and management, thanks to which the negative impact of the Project will not affect individual groups reporting problems.

[Chapter V.6] also contains an extended analysis of legal and factual conditions, the necessity or lack of need for the establishment of a restricted use area for the Nuclear Power Plant, and [Chapter V.7] provides an overview of proposals for the scope of monitoring of biotic and abiotic components of the environment, broken down into the construction and operational phases of the Project.

Volume V ends with [Chapter V.8], which describes the difficulties arising from the technical deficiencies or gaps in modern knowledge encountered in the preparation of the EIA Report, which were related in particular to the uniqueness of the Project, the wide range of the analyses performed and the large survey area.

V.1 Description of the forecasting methods used

V.1.1. Natural environment

V.1.1.2 Marine area

The forecasting methods used for surveys of biotic components of the marine natural environment are based on the best available national and international practices in the field of environmental impact assessment. The General Directorate for Environmental Protection (GDOŚ) has made available a number of online resources [148] providing guidelines for the conduct of environmental surveys and preparation of EIA reports. They were used to develop an assessment methodology along with best practices based on international guidelines for the preparation of the EIA Report documentation.

Environmental data from the area subject to impact assessment was collected as part of field surveys/inventories preceded by detailed desk studies aimed at identifying archival and current references on the occurrence of individual taxa or their groups in the analysed area. The results of the studies were developed using statistical methods allowing biodiversity to be assessed using biodiversity indicators or ecological relationships between taxa and environmental parameters in relation to both analysed site variants. In cases where the collected data did not allow for the use of statistical methods, expert knowledge and literature data were used to develop and compare the results obtained. To develop the acquired spatial data, the geographical information system (GIS) software was used.

Potential sources of impact were identified on the basis of the maritime infrastructure associated with the planned Project and the related construction methods (including indirect effects of construction on land). The list of potential receptors was drawn up on the basis of the natural characteristics of the marine environment, based on the results of a number of environmental surveys carried out in the marine survey areas designated for both variants considered.

Where appropriate, the range of impacts was based (e.g. temperature, noise or water quality elements) on combined summer and winter modelling results and on aggregated change calculations for the 98th percentile [123], [72]. These zones then formed the basis for all the impact assessments contained in this report. Where appropriate, these zones of impact have been elaborated further, at the Project level, using information specific to the impact receptors, e.g. known auditory sensitivities of marine mammal species. Where the sensitivities and the zones of impact overlap, this implies the presence of a potential impact pathway, which was then described and appropriately evaluated.

The scale of impacts generated by the Project was determined against a scale ranging from negligible to high values based in justified cases on best practice guidelines (e.g. recommendations of GDOŚ or the Chartered Institute of Ecology and Environmental Management, CIEEM) and relevant legal standards.

Impact on marine protected sites and objects was assessed using a process referred to as Habitats Regulations Assessment (HRA). The first stage of the habitat assessment (Screening) was to determine the potential impact of the Project on European sites. If a significant impact in the site could not be ruled out, the Appropriate Assessment (AA) was carried out as the next step for these sites [45].

A detailed approach to environmental forecasting for the natural environment on land and sea is described in [Chapter IV.1] and [Chapter IV.2].

V.1.7. Surface water

V.1.7.2 Marine surface water

The analysis of the impact on marine surface water was carried out on the basis of the same methodological procedure as with inland surface water, with the following differences:

Hydromorphological assessment methods:

The hydromorphological assessment of selected watercourses and the assessment of the impact of the Project on hydromorphological elements was based on the methodology for testing and assessment of hydromorphological elements of transitional and coastal waters adopted by the Institute of Meteorology and Water Management (IMGW) [39].

Quantitative assessment methods:

DELFT3D – a hydrodynamic, multidimensional programme for hydrodynamic simulations was used, which calculates the phenomena of non-laminar flow and transport of matter resulting from tidal and meteorological forces. The primary goal of the Delft3D-FLOW computational model is to solve various one-, two- and three-dimensional, time-dependent, nonlinear differential equations related to hydrostatic problems of free surface flow.

A detailed approach to the forecasting process is set out in [Chapter IV.8.3].

V.1.13. Ionising radiation

This chapter provides a description of the modelling of the spread of radioactive substances in operational states and the determination of doses. The operational emission data was based on the information obtained from the AP1000 technology provider [148]. The operational emission values in this document were appropriately revised, corrected and supplemented by comparing them with the data contained in the documents [10], [133], [24].

Radiological impacts in operational states are modelled on the basis of source terms derived from the plant vendor's hitherto operational experience with pressurised water reactors (PWRs). Annual emissions are estimated assuming operation with a maximum fuel failure level corresponding to the coolant activity limit, in compliance with the technical specifications. In addition, the emissions were verified in accordance with the aforementioned documents:

- for emissions into the air, the data provided by Westinghouse was used, supplemented by data from the report [24]; the data is presented in [Chapter II.10.2],
- for emissions into surface water, the data provided by Westinghouse was used, supplemented by data for H-3 and C-14 from the report [24]; the data is presented in [Chapter II.10.4].

The basic data for the main plant vent, adopted for the UK AP1000 generic design [24], is as follows:

- vent stack height 75m above ground level (AGL), cloud elevation 6.7 m, rectangular stack of dimensions 2.025 m x 2.311 m,
- volumetric flow rate: 38.12 m^3/s, nominal discharge velocity: 8.15 m/s,
- exhaust gas temperature: 12 – 42°C (285–315°K) (depending on the external temperature).

This height of the main plant vent was finally adopted for the calculation of the radiological impact of the NPP in operational states at the coastal site of Lubiatowo - Kopalino (Variant 1). For the Żarnowiec site (Variant 2), the main plant vent height was 150 m AGL – due to the height of the surrounding hills exceeding 100 m AGL.

Modelling the spread of radioactive substances emitted into the atmosphere and associated doses

<u>Description of the dispersion models for radioactive substances emitted into the atmosphere</u>

The modelling of the dispersion of radioactive substances released into the atmosphere is based on two numerical code packages: the real-time online decision support system (RODOS) for emergency management after nuclear accidents, developed under a number of European Union programmes (since 1991) and used e.g. at the Radiation Emergency Centre (CEZAR) of the National Atomic Energy Agency (PAA), and the PC-CREAM programme developed by the Health Protection Agency in the United Kingdom. A detailed description of the models of the spread of radioactive substances is provided in [Appendix V.1.13-1].

Methodology for the use of meteorological data

The Atomic Law Act of 29 November 2000 [146] does not specify a method for the selection of meteorological data – it contains a general statement: *"When estimating the effective dose , ... data and information on the [...] site of a nuclear facility, including the natural environment conditions prevailing in the area of the nuclear facility, in particular landform, geological structure, climatic conditions, taking into account the most adverse meteorological conditions [...]"*.

To determine weather sequences, data from the Łeba weather station were used, for which data was obtained for the years 1973–2016 and for the 24-month monitoring period in Variant 1 – Lubiatowo - Kopalino site and Variant 2 – Żarnowiec site (April 2018 – March 2020).

Given the fact that the way of taking into account the most adverse meteorological conditions can be interpreted differently, i.e. on the basis of:

a. the duration of atmospheric inversions,

b. the selection of conditions conducive to the long-distance transport of particles, or

c. the selection of conditions conducive to high exposures (i.e. concentrations of substances or radionuclide activities), and radionuclide depositions leading to radioactive contamination of land and water,

three different methods for the selection of meteorological data were developed, corresponding to points (a) - (c).

The implementation method in each of the variants involved a two-stage process. In the first stage, the reference year for the variants concerned was determined as follows:

a. sequences with continuous categories of atmospheric stability were analysed. The reference year chosen was that for which the sum of their durations is the largest – it was 2005,

b. the prevalence of wind stronger than 10 m/s in the direction covering the Tri-City was analysed (taking into account that it is the largest population centre near the potential nuclear power plant sites). 2012 turned out to be the reference year,

c. the simultaneous prevalence of the most stable classes and precipitation were analysed – in this case the reference year was 2010.

It should be noted here that the latest data obtained from the 24-month monitoring period at both sites did not change the selection of reference years, as the indicators obtained for them in accordance with the presented methods (a) – (c) were significantly lower than the corresponding indicators for the reference years 2005, 2012 and 2010.

At the second stage, for each variant, approximately 5% of the sequences with the worst meteorological conditions was selected from the reference year found in the first stage as follows:

a. the longest-running sequences with continuous categories of atmospheric stability were selected – a total of 36 data sets,

b. the sequences with the largest range were selected – a total of 36 data sets,

c. in this case, Flexpart simulations were carried out to determine the amount of exposure and deposition in the land area at a distance of 50 km from the release site. As a result, 41 sequences were selected – those that gave the largest aggregate exposures and depositions in the area. In order to obtain the meteorological data input to Flexpart, simulations were first carried out using the Weather Research and Forecasting (WRF) model with data assimilation.

This way, 36+36+41=113 meteorological sequences were selected, plus two special sequences from 1995 for which Austrian institutes carried out simulations commissioned by Greenpeace. Thus, a total of 115 weather sequences were obtained [2], [3].

At the same time, taking into account the fact that the latest data from the 24-month monitoring period came directly from the considered suitable site of Lubiatowo - Kopalino or Żarnowiec, it was concluded that although the data did not change the reference years, it was advisable to include meteorological sequences from that period in the analysis. Therefore, additional 44 sequences were selected for each site from the period between April 2018 and March 2020, in accordance with the methods described in points (a), (b), (c), i.e. taking into account all three variants of sequence selection. As a result, the total number of selected meteorological sequences is 159 for each site, but these are not identical sequences for the period between 2018 and 2020.

At the same time, statistical calculations were made to determine the average meteorological conditions. For this purpose, the probabilities of occurrence of various combinations of basic meteorological parameters such as wind direction, wind strength and stability category were determined.

The wind direction was determined for 16 sectors (more precisely, the sector determined where the wind was blowing from). Wind speeds were then divided into 7 groups. For each sector, and for each combination of wind force groups and stability category, the frequency of occurrence of such a combination was determined on the basis of multiannual statistics (i.e. for the period between 1973 and 2016). This way, the combined probabilities of the occurrence from a specific sector and wind force group were determined, together with stability categories. It should be added here that a large part of these probabilities are zero, which is obvious in that there are correlations between wind strength and stability categories (some combinations cannot occur).

[Appendix V.1.13-2] provides a full set of meteorological sequence dates for the reference years and for the 24-month monitoring period in both site variants.

Method of dose calculation for operational states

The simulation calculations were performed in two stages. The first, initial stage consisted in performing verification calculations by means of the RODOS system using data for 2010, i.e. the reference year for deposition and exposure. At the same time, since the RODOS system does not enable the calculation of doses resulting from operational emissions for tritium and carbon C-14, they had to be calculated using different software – the PC-CREAM package was used for this purpose. Subsequently, similar calculations were made for all radioactive substances using the PC-CREAM package. It turned out that the dose values obtained from the PC-CREAM package were then those determined by the RODOS system (often by an order of magnitude), and therefore provide more conservative results. As a consequence, the PC-CREAM package was used in the second stage, both for meteorological data for the reference year 2010 and selected sequences from the 24-month monitoring period – meteorological data was based on statistics from these periods (separately for the multi-year period and for the 24-month monitoring period).

The calculations using the PC-CREAM package were based on four basic models: PLUME (transport and dispersion in the atmosphere), FARMLAND (food dose module), GRANIS (dispersion in soil) and RESUS (model of resuspension in air). When calculating doses, a selection of options with conservative ("critical") model parameters was used.

Modelling the spread of radioactive substances emitted into surface water and associated doses

Description of the models of the spread of radioactive substances emitted into surface water

As a basic tool for modelling the spread of radioactive substances to surface water, the RODOS hydrological model chain (HDM – Hydrological Dispersion Module [153], [85], [154] was used. It contains models of contamination transport and dispersion in the aquatic environment (rivers, reservoirs, lakes, estuaries, coastal and marine waters) and the transfer of radionuclides from atmospheric deposition to various water bodies. The baseline data of HDM hydrological models consists of simulated concentrations of radionuclides in water, sediments and fish, which are used by the FDMA aquatic food chain sub-model – dose module [69], which complements the basic FDMT dose model of the RODOS system. FDMA makes it possible to simulate the transfer of radioactive substances from contaminated water and fish to humans by ingestion, taking into account both direct consumption of contaminated drinking water (and fish) and indirect contamination through feeding of farm animals and as a result of cropland irrigation (i.e. through the irrigation system). This model is also used in the decision-making process regarding the introduction of countermeasures in the aquatic environment. The HDM system consists of the following models: RETRACE, RIVTOX, COASTOX, THREETOX and POSEIDON, supplemented by the FDMA module mentioned above. A detailed description of the models of the spread of radioactive substances is provided in [Appendix V.1.13-1].

Method of dose calculation for operational states

Dose calculations for liquid emissions in operational states were made using the POSEIDON-R model. It was assumed that liquid emissions would be transported by pipeline to the sea to a distance of at least 700 m from the coastline – in the case of an open cooling water system by discharging heated cooling water, and in the case of a closed system by a desalination discharge pipeline. Calculations were made for sequences from the reference year (from the point of view of meteorological data) 2010 for a period of three years starting from 2010. Due to the fact that the information about the source refers to annual volumes without giving details about the frequency of discharges, an even and continuous release over the year was assumed. A very conservative assumption was also made that 50 kg of locally caught fish is consumed by an adult per year.

In the case of emissions into the atmosphere and deposition of radioactive substances into land and water areas, estimates made for accident conditions showed that surface water contamination provides a small contribution to doses. It should be noted that emissions in operational states are several orders lower than the magnitude of emergency releases in a severe accident, which last about a month. It follows from this difference that the estimates of effective doses from all exposure pathways for accident conditions, conservatively counting, will be at least two orders of magnitude higher than the corresponding doses for operational states. As the calculations for accident conditions will show, waterborne doses will provide a minimum contribution to the total doses. This means that doses from the “water path” for operational emissions are generally negligible.

Modelling of the spread of radioactive substances in groundwater

Description of the models of the spread of radioactive substances released into groundwater or its indirect contamination

In the case of the AP1000 reactor, the direct release of radioactive substances into groundwater is practically excluded, both in operational states and in assumed accident conditions, i.e. in the case of a bounding design basis accident and a severe accident considered in the design extension conditions, which is a severe accident considered in DEC, representative also for emergency planning. Therefore, groundwater can only be contaminated indirectly from releases into the air, followed by the deposition of contaminants on the land surface and their transport in the ground to groundwater. Thus, the modelled phenomena involve the deposition of radioactive contamination from the air on the land surface and its transport in the ground to groundwater and then in groundwater to surface water. The modelling of the spread of radioactive substances in groundwater was carried out using MODFLOW [33]. A detailed description of the models of the spread of radioactive substances is provided in [Appendix V.1.13-1].

Method of dose calculation for operational states

The only groundwater contamination pathways in the case of operational states is through deposition on the soil and the migration of radioactive substances into groundwater. Liquid emissions are discharged directly into the sea, so they do not provide any contribution to groundwater contamination. Estimates showed that the processes of soil contamination and migration to waters are significantly slower and can at most make a small contribution of several percent to surface water contamination, and with a long delay at that (at least several months).

A detailed description of the methods for forecasting ionising radiation is provided in [Chapter IV.14].

V.1.14. Human health and life

In preparing the assessment of the impact on human health and quality of life, the process of identifying and assessing potentially significant adverse and beneficial effects of the Project was used. The assessment takes into account the aspects related to the avoidance or reduction of potential threats to human health and life as well as the use of opportunities to improve health and quality of life, and uses the information included in the study [analysis] [5].

The assessment used the definition of "health" adopted by the World Health Organization (WHO) in its 1948 Constitution, where it is defined [49] as "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*".

Quality of life is defined by the WHO Quality-of-Life Group (WHOQOL) [32] as "*individuals' perceptions of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns*". In addition to the general definition, the WHOQOL quality of life studies also specify the spheres of life that must be taken into account to grasp the essence of the phenomenon. These are: physical and mental health, level of independence from others, social relationships, personal beliefs of the individual and the impact of these personal beliefs on the environment in which the individual lives (WHOQOL Group 1994, Rapley, 2003) [92].

The assessment of impact on human health and quality of life also used the concept of mental health defined by the WHO in 2004 as: "*a state of well-being in which an individual realises his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community*".

For the purposes of an assessment of the impact on human life and health, based on the results of the analyses carried out as part of the current state [Chapter III.4.7], the potential impacts of the Project for Variant 1 – Lubiatowo - Kopalino site and Variant 2 – Żarnowiec site were analysed, taking into account, among other things:

- impact of emissions from the NPP on human health and life,
- impact of the Project on the health and life of the local community,
- impact of the Project on the health and life of employees hired for the construction of the NPP,
- impact of the Project on the health and social care system in the region.

The assessments took into account factors contributing to better or worse health or quality of life, including:

- Physical living environment, i.e. access to drinking water and clean air, good housing and working conditions, social ties, safe roads, areas and places;
- Employment and working conditions;
- The impact of ionising radiation from the NPP on human health, both of workers and local residents;
- The impact of radioactive emissions on food of marine and land origin;
- Social support, including support from families, friends and communities, affecting health, including mental health and quality of life;
- Fostering family customs, ties and traditions giving a sense of community, their impact on mental health and quality of life;
- Genetics, due to the fact that genetic conditions will reflect an increased probability of developing a disease based on the genetic structure of an individual (e.g. LCHAD deficiency – long-chain 3- hydroxyacyl-coenzyme A dehydrogenase deficiency – occurs in the Kashubian region).
- Lifestyle and coping methods that affect physical and mental health and quality of life;
- Health services and access to disease prevention or treatment services, which has an effect on overall health;

- Income, social status and education, which influence health, including mental health.

The assessment of impact on human health and life also proposed measures and methods to reduce both the level and effects of impacts in order to avoid or reduce potential health risks.

For impacts related to ionising radiation, radiation risk models recommended by the International Commission on Radiological Protection (ICRP) were used [60]. These are conservative models, based on the assumption of a linear increase in cancer risk even for the smallest doses. Based on the estimated doses for members of the public and future NPP employees, calculated values of radiation risks (that is, the probability of developing fatal cancer, i.e. the stochastic effect) for the whole body and its individual organs were presented. The resulting risks are completely insignificant (fractions of a percent). A comparison of the estimated doses with the applicable legal requirements was also made, both for members of the public and for employees of the future NPP.

By means of tools including the RODOS model used by the National Centre for Nuclear Research (NCBJ) [3], [153], the maximum possible depositions of radioactive substances in food (including agricultural produce) from both sea and land were estimated. The calculation method is also used by the National Atomic Energy Agency. The results obtained showed that the concentrations of radioactive substances in food would be completely insignificant.

A detailed description of the methods for forecasting the impact on human health and life is provided in [Chapter IV.15].

V.1.16. Severe accident

The characteristics of releases of radioactive substances from the NPP into the environment in accident conditions (source term) were based on information obtained from the AP1000 technology provider [148]. At the same time, these source terms were estimated based on conservative assumptions. They comply with the guidelines of the US Nuclear Regulatory Commission (NRC) [71] and were verified by the UK Office for Nuclear Regulation (ONR) based on the results of the analyses carried out for the AP1000 reactor.

As described in Volume II [Chapter II.11.4.2] and in Volume IV [Chapter IV.17], on the basis of the information obtained from the AP1000 Plant Vendor [148], two accident types representing the following categories were considered as severe accidents representative in terms of plant off-site radiological impact in accident conditions:

- accident without core melt: a bounding design basis accident was assumed, which, for the AP1000 reactor, is a large-break loss-of-coolant accident (LB LOCA),
- severe accident with core melt considered in design extension conditions, which is also an accident representative for emergency planning purposes.

In the event of accident without core melt, i.e. LB LOCA, the releases of radioactive substances were determined assuming 33% fuel failure (i.e. damaged fuel element cladding), as a result of which all radioactive substances contained in the gap between the fuel pellets and the cladding tubes are released into the containment (gap release). It was assumed that the fraction of activity contained in the gap represents 5% of the activity contained in the reactor core for each group of the released nuclides. In addition, it was assumed that all the activity contained in the reactor cooling system was released from the containment through the containment air filtration system (VFS) prior to the start of fuel failure, assuming that the coolant activity was then at the maximum level allowed in the technical specifications.

The characteristics of releases of radioactive substances from the NPP into the environment in the event of a severe accident with core melt considered in design extension conditions and representative for emergency planning are taken from the same document [148]. In this case, in-vessel core melt retention is assumed with external cooling, i.e. heat dissipation through the walls of the vessel. During such an accident, fission products are released from the core into the containment. When determining the fission product source term to the environment, the reduction of the activity of radioactive substances in the form of aerosols in the containment was taken into account, resulting from gravitational settling and phoretic deposition (i.e. with deposition on water droplets and transport) of radioactive aerosols inside the containment. Iodine depositions were also estimated, with a reassessment of their interaction with unbuffered open water bodies and water layers that may form inside the containment. The blocking of aerosol flow through nominal leaks from the containment into the environment was taken into account, while their deposition inside the auxiliary building was not taken into account.

As part of the analysis of the dispersion of radioactive substances and the determination of doses in the NPP surroundings in accident conditions, the following modelling processes were performed:

- Modelling of the dispersion of radioactive substances and determination of doses at a distance of up to 30 km from the NPP, which included:
  - Modelling of the dispersion of radioactive substances released into the atmosphere and determination of doses associated with those releases;
  - Modelling of the transport of radioactive substances to surface water bodies and determination of doses associated with their contamination;
  - Modelling of the dispersion of radioactive substances in groundwater;
- Modelling of the dispersion of radioactive substances and determination of doses at a distance of more than 30 km from the NPP, including in the transboundary context:

As part of the modelling, trajectory analyses of the dispersion of radionuclides and meteorological data provided by IMGW were used. Due to the high complexity of the modelling descriptions and the way the trajectory is analysed, this information is included in [Appendix V.1.16-1].

A detailed description of the methods for forecasting a severe accident is provided in [Chapter IV.17].

V.2 Selection of the variant proposed by the Investor, rational variant most favorable for the environment, and rational alternative variant, along with reasoning for their selection

V.2.1 Introduction

The selection of the variant proposed by the Investor, rational variant most favorable for the environment, and rational alternative variant presented in this report is a complex assessment process consisting of two separate but interlinked analyses:

- The site comparison analysis focused on specific features of two candidate sites for construction of Poland's first nuclear power plant: Lubiatowo - Kopalino, and Żarnowiec. The comparative site analysis compared each site against more than 100 different criteria including, in particular, exclusion criteria so that a selection of a preferred location could be made in accordance with the requirements outlined in the GDOŚ Decision;
- The multi-criteria analysis of the sites under consideration, together with the sub-variants that can be implemented in each site (three technical sub-variants in Variant 1 - Lubiatowo-Kopalino site, and two in Variant 2 - Żarnowiec site) was aimed at determining the rational most favorable for the environment variant, the variant proposed by the Investor, and the rational alternative variant. The multi-criteria analysis took into account the technical differences between the sub-variants, resulting i.a. from the site conditions, and also considered differences in the environmental and socio-economic impacts resulting from the implementation of each sub-variant at every considered site.

The comparative analysis consists of steps in which the assessment criteria for the individual sites were identified and defined; each of the sites was then assessed against the defined criteria. The adopted criteria and their scoring are based on the international and national guidelines, including the current provisions of the law, taking into account exemplary similar projects. The criteria adopted in site assessment include i.a. exclusion criteria derived directly from the regulation [of the Council of Ministers] of 10 August 2012 on detailed scope of assessment with regard to land intended for the location of a nuclear facility, cases excluding land to be considered eligible for the location of a nuclear facility and on requirements concerning site [evaluation] report for a nuclear facility (siting regulation) [108], in the case of which failure to meet even a single one would result in a given site being excluded. The final stage of the assessment involved evaluating the environmental impact of the NPP to identify potential impacts and applying possible mitigation measures to minimize the environmental impact for each site under consideration. The result of the comparative analysis was the identification of the preferred site from the perspective of technical aspects.

The multi-criteria analysis takes into account the results of the comparative analysis for the sites under consideration with their five sub-variants:

- Variant 1 – Lubiatowo-Kopalino site -- Sub-variants: 1A - open cooling system 1B - closed cooling system using seawater; 1C - closed cooling system using desalinated seawater;
- Variant 2 - Żarnowiec site - sub-variants: 2A - closed cooling system using seawater; 2B - closed cooling system using desalinated seawater.

The multi-criteria analysis identifies and defines evaluation criteria used to examine a certain site, taking into account the sub-variants under consideration. Each sub-variant was then assessed against a set of specific criteria. The significance of each criterion was determined with the use of the analytical hierarchy process. DecisionVue, a specialist tool designed for this purpose, was used to perform the analysis. DecisionVue is used in large-scale investment projects. Both the weights and the scoring were subjected to an extended sensitivity analysis and validation with the use of the DecisionVue tool. The outcome of the multi-criteria analysis is a site ranking with sub-variants and the designation of the variant proposed by the Applicant, the rational alternative, and a rational variant most favorable for the environment.

V.2.1.1 National and international laws, regulations and guidelines

NPP site selection is a multi-step process and culminates in the indication of a preferred site. The process is designed to consider as many sites as possible and then apply exclusionary and comparative criteria to identify the most favorable sites/locations. The use of exclusionary and comparative (or discretionary) criteria to analyze potential sites for planned nuclear facilities is an established and common practice that is applied at both the strategic and design levels.

The standard site selection process is shown in Figure [Figure V.2- 1].

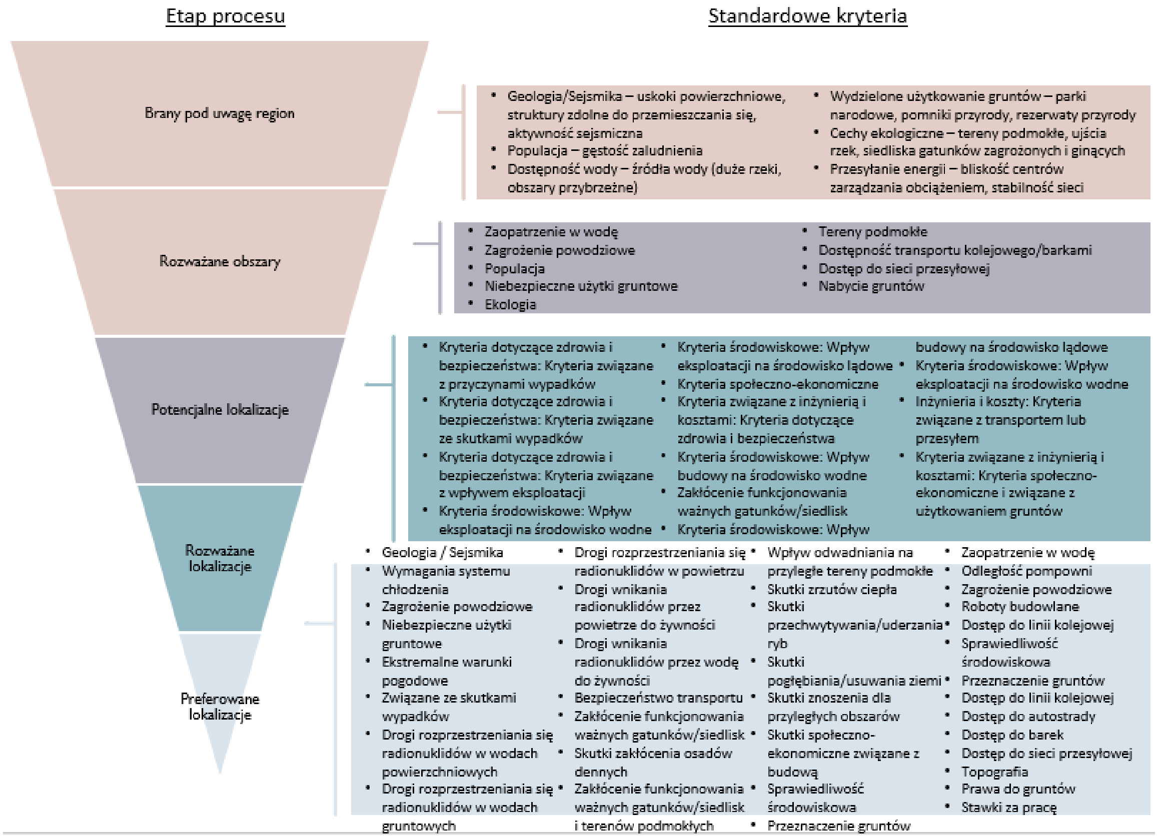


Figure V.2- 1 Standard site selection process

Process Stage	Standard Criteria
Region in question Area in question	Geology/Seismic – surface faults, structures capable of movement, seismic activity, Population density, Water – available sources of water (large rivers, water bodies), Restricted land use – national parks, nature reserves and monuments, Ecological features – marshes, estuaries, habitats of endangered species., Energy transmission – proximity of load management centers, grid stability
Potential sites	Water supply, Flooding, Population, Hazardous land use, Ecology, Marshlands, Availability of railway/barges, Access to grid, Land purchase
Considered sites	Health and safety criteria: causes of accidents, Health and safety criteria: results of accidents, Health and safety criteria: impact of operations, Environmental criteria: Impact of operations on water environment, Environmental criteria: Impact of operations on terrestial environment, Socio-economic criteria, Engineering and cost criteria: Health and safety, Environmental criteria: Impact of construction on water environment, Disruption to key species/habitats, Environmental criteria: Impact on terrestrial environment, Environmental criteria: Impact of operation on water environment, Engineering and cost: Transport and transmission criteria, Engineering and cost: Socio-economic and land us criteria
Preferred sites	Geology/Seismic, Cooling system, Flooding hazard, Dangerous land use, Extreme weather conditions, Accidents, Dispersion paths of radionuclides in surface waters, Dispersion paths of radionuclides in ground waters,

	Dispersion paths of radionuclides in the air, Ingestion paths of radionuclides in food chains, Ingestion paths of radionuclides in food chains via water, Transport safety, Disruption to key species/habitats and marshlands, Impact of drainage on marshlands, Impacts of heat sink, Impacts of fish impingement/entrainment, Impacts of excavations/earth displacement, Impacts of earthworks to adjoining areas, Socio-economic impacts from construction, Environmental justice, Land use, Water supply, Distance to pump stations, Flood risk, Construction works, Access to railways, Access to highways, Access to barges, Access to grid, Topography, Land titles, Labor wages.

Source: [151]

Exclusionary criteria include criteria that, if they cannot be met (there are no mitigating measures for them), categorically exclude a potential site from further consideration in the site selection process. These criteria generally address attributes such as events, phenomena, or hazards for which there are no practical engineering solutions and for which it will not be possible to meet appropriate regulatory or statutory requirements [108]. Exclusion criteria are usually considered early in the site selection process (for example, during Steps 1 and 2 of the IAEA's site selection process [43]), in order to avoid unnecessary expenditure of time and resources on further analysis of such sites.

Discretionary criteria include criteria that may, on their own or in combination, indicate a preferred site for an NPP. These criteria should be evaluated in terms of whether there is a realistic possibility that any potential significant adverse impacts will be adequately mitigated (in whole or in part) or whether the impacts will be so severe (with respect to factors such as cost, schedule, and environmental damage) that they should preclude the implementation of the project at a given site/location.

V.2.1.2 Site selection

V.2.1.2.1 Site selection in 2011

The site selection process of a nuclear power plant comprises a series of activities to be executed “step-by-step” to enable the selection of a site from less to more detailed criteria - covering first the geographical region and then the specific aspects of a particular location, including availability of water sources, distance from high risk facilities and other criteria characteristic for the site to provide evidence that the location is safe for the operation of the unit. The site selection process is, among other things, a quantitative review of potential sites to evaluate multiple pre-designated locations for a planned power plant and to narrow the number of options to only those sites/locations that can be analyzed in more detail once a rigorous set of exclusion criteria is met. In 2011, while preparing a site selection methodology, PGE Polska Grupa Energetyczna S.A. and PGE Energia Jądrowa S.A. (jointly PGE) - the Investor's former partners - engaged CH2M HILL to lead the entire process. Additionally, PGE enlisted the support of Pöyry to create a reliable and comprehensive set of scoring and weighting criteria. Figure [Figure V.2- 2] shows a cross-sectional view of the entire site selection process.

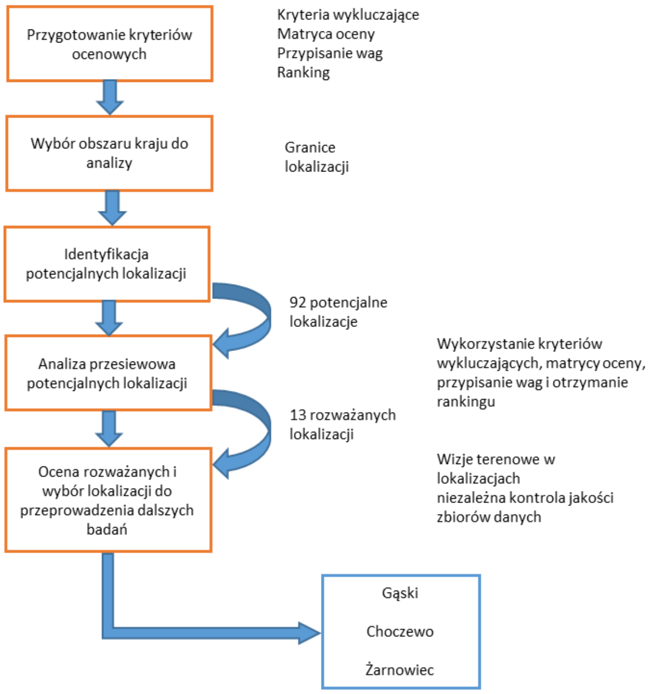


Figure V.2- 2 Diagram of the site selection process carried out in 2011

Development of evaluation criteria	Exclusion criteria Evaluation matrix Weights assigned Ranking	
Selection of region for analysis	Site boundaries	
Identification of potential sites		
	92 potential sites	
Screening of potential sites		Application of exclusion criteria, evaluation matrix, assigned weights and establishing the ranks
	13 considered sites	
Evaluation of considered sites and selection of sites for further analysis		Field visits in sites Independent review of data quality
	Gąski Choczewo Żarnowiec	

Source: In-house study based on [120]

First, PGE, with the support of CH2M HILL consultant, prepared exclusion criteria to screen designated sites, and used those criteria to arrive at a Considered Sites shortlist. PGE commissioned Energoprojekt-Katowice (EP-K) and Energoprojekt-Warszawa (EP-W) to determine additional potential sites based on exclusion criteria. CH2M HILL and Pöyry jointly developed the evaluation criteria and scoring matrix used to evaluate the Considered Sites shortlist. PGE has defined the survey area for the preliminary site selection of the NPP as the area located north of the Warsaw-Poznań line, and west of the Warsaw-Olsztyn line.

The survey area was selected taking into account the following:

- Careful consideration of the current strategic electrical power needs and reliability of the national power system;
- A situation in which demand for electricity in northern Poland exceeds supply capacity, while most of the nation's generating facilities are located in southern Poland; and
- Key siting aspects such as access to good sources of cooling water and lower seismic activity.

PGE subsequently narrowed the study area by excluding the area within 100 km of the Polish-German border due to the planned expansion of an existing power plant in northwestern Poland and to minimize the assessment of transboundary environmental impacts.

As a result of the preliminary selection process, 92 Potential Sites/Locations were identified, including 27 identified in earlier studies by the Polish Ministry of the Economy. 92 Potential Sites were screened using an agreed upon set of exclusion criteria, with the intent of narrowing the number of sites for more detailed analysis. This review resulted in the selection of 13 Considered Sites within the study area, which were evaluated using more detailed site-specific data.

Table [Table V.2- 1] lists the 9 exclusion criteria used to exclude the Potential Sites and arrive at 13 Considered Sites.

Table V.2- 1 Exclusion criteria applied during site selection in 2011

No.	Exclusion criterion	Description
1	Distance to the Baltic Sea or a river	The distance from the site boundary does not exceed 15 km from the Baltic Sea or a river with adequate flow (the intake from which will provide cooling for the nuclear power plant). This criterion requires identification of a protected area located between the site and the water source.
2	Distance from high voltage line (400 kV)	The distance from the existing/planned high voltage line (400 kV) does not exceed 80 km.
3	Site area	The site area is not less than 150 ha. The shape of the location is not too elongated (length to width ratio does not exceed 4:1)
4	Low population density	The site and the area surrounding the site within 3 km of the site boundary is sparsely populated (single-family residential development is permitted).
5	Distance from village, town or city	The distance to the nearest village, town and city with population of 500, 2,000, 10,000 respectively is not less than 3, 5 and 8 km.
6	Site area characteristics	The site is not located in wetlands, marshes, floodplains or depressions.
7	Height above sea/river level	The location area is not too high above the sea or river level.
8	Protected/conservation sites/areas	The site is located outside protected/conservation sites/areas (Natura 2000, nature reserves, national parks).
9	Distance from population centers	The distance from the site to a population center with a population equal to or greater than 20,000 inhabitants is not less than 16 km.

Source: In-house study based on [120]

Individual nuclear siting experts reviewed the available data and used specific scoring methods to score the various criteria and sub-criteria. These results determined the values that were entered into the weighted ranking matrix to obtain a final ranking of the 13 Considered Sites. The sites were analyzed using a wide range of publicly available information to determine their relative ranking based on the site rating criteria. This detailed evaluation uses a scoring and weighting process that is intended to be reliable, repeatable, and provide sufficient arguments for external reviewers. Data collection, data analysis, and scoring processes were applied to the 13 Considered Sites, relying on sources of relevant data from EP-K and EP-W, and data and information obtained from publicly available sources. A wide range of information was used when conducting general site-specific screening assessments. The key issues included in the exclusion and evaluation criteria are shown in the figure [Figure V.2- 3].

Kryteria wykluczające

- ✓ Odległość od Morza Bałtyckiego lub rzeki
- ✓ Odległość od linii wysokiego napięcia (400 kV)
- ✓ Powierzchnia terenu lokalizacji
- ✓ Niska gęstość zaludnienia wokół lokalizacji
- ✓ Odległość lokalizacji od wsi/miasta
- ✓ Charakterystyka terenu lokalizacji
- ✓ Wysokość nad poziomem morza/rzeki
- ✓ Lokalizacja poza obszarami chronionymi
- ✓ Odległość od skupisk ludności

Kryteria ocenowe

Kryterium	Waga [%]	Liczba podkryteriów
Powierzchnia terenu	15	6
Zagrożenia sejsmiczne/geologiczne	5	4
Geotechnika	5	2
Dostępność wody chłodzącej	15	9
Sieć przesyłowa	10	2
Infrastruktura transportowa	10	3
Aspekty dot. technologii jądrowych	15	6
Aspekty socjoekonomiczne	5	4
Rozprzestrzenianie się substancji promieniotwórczych	5	3
Kwestie środowiskowe/legislacyjne	15	4
Razem	100	43

Figure V.2- 3 The key issues included in the exclusion and evaluation criteria in 2011

Exclusion citeria	Evaluation criteria		
✓ Distance from the Baltic sea or a river ✓ Distance from HV line (400 kV) ✓ Site area ✓ Low population density around site ✓ Distance to villages/city ✓ Terrain characteristics ✓ Elevation above sea/river ✓ Outside protected areas ✓ Distance from population centers	Criterion	Weight [%]	No of subcriteria
	Size of site	15	6
	Seismic/geological hazards	5	4
	Geotechnical	5	2
	Access to cooling water	15	9
	Transmission grid	10	2
	Transport infrastructure	10	3
	Nuclear technology related	15	6
	Socio-economic	5	4
	Dispersion of radioactive substances	5	3
	Environmental/legal issues	15	4
	Total	100	43

Source: In-house study based on [120]

To further narrow down the analysis to a final review of sites, CH2M HILL's internal site selection analysis specialists (a peer review by experts not involved directly with the analysis carried out for PGE) were asked to consider plausible plant layout scenarios and cooling water system configurations to test the scoring criteria against more theoretical engineering concepts. This allowed the scoring methods to be refined to better match the likely NPP design requirements, particularly with respect to site-specific cooling water system configurations.

PGE staff then visited several sites that ranked the highest to verify/confirm the information obtained from websites and other publicly available data sets. This led to the re-evaluation of some sub-criteria to include information that had not been previously identified. As part of the planned overall evaluation process, a more detailed evaluation was conducted for the 13 Considered Sites. This included independent quality control of datasets, assessments, and substantiation by subject matter experts to ensure high reliability of results. Quality controls included the use of more detailed data sets, such as more recent census data, detailed mapping, and topographic data that were not initially available from public sources. The sites were then evaluated by subject matter experts to determine a baseline ranking of sites. Once a baseline sites ranking was established, the entire process was then subjected to a comprehensive sensitivity analysis in order to test it for the possible influence of underlying factors or assumptions that could have potentially biased the site selection criteria (inherent biases) or unintended undue emphasis on any particular criterion. The sensitivity analyses showed a consistent set of results for the site assessment.

The two best rated sites, Gąski and Choczewo, are located in the Zachodniopomorskie and Pomorskie Voivodeships, respectively. Both sites are adjacent to the Baltic Sea with unrestricted water access and a short waterway corridor, which means that a once-through cooling water system would be possible at these sites/locations. Sites located within a short distance (less than 1 km) from such an unrestricted cooling water source scored well in the evaluation due to the significant technical, commercial, and environmental advantages of such configurations. The cooling water system evaluations clearly showed that access to cooling water and assumed cooling water system configurations had a significant impact on site selection for further study. Surface and subsurface geologic conditions appear to be generally favorable for NPP construction at these two sites. Both sites also have possible access to a rail line that could be extended within a reasonable distance of the site.

It should also be borne in mind that the coastline and coastal waters along the northern boundary of the two sites are protected Natura 2000 sites that could be temporarily disturbed during construction works of the water intake and water discharge pipelines from the NPP (assumed to run underground). Both sites are also adjacent to Natura 2000 sites. The proximity of these Natura 2000 sites should have been further investigated as part of the Site Characterization to determine potential impacts on these sites during construction and operation of the NPP. In addition, due to the short distance between the coast and the flat or gently rising terrain of both sites, the maximum likely flood wave associated with sustained high-speed winds had to be evaluated to ensure that these external events were adequately accounted for in any subsequent land development activities.

In addition to coastal sites, Żarnowiec was identified as a site that had been designated in the past for NPP construction (i.e., it is a brownfield site with the potential for installation of a cooling system). Given that this site had been considered for an NPP before, it would be prudent to evaluate it further for the appropriateness of using the site for construction of the planned nuclear power plant. Such an assessment would provide a risk mitigation strategy for site characterization in the event that either of the above two coastal sites assessed is deemed unacceptable for any reason. Accordingly, it was recommended that the Żarnowiec site be considered following a more thorough evaluation of the issues related to existing conditions (including the cost and timing of site development prior to construction).

Ultimately, three sites were selected: Gąski, Choczewo and Żarnowiec.

V.2.1.2.2 Cancellation of Gąski site

The Gąski site was identified as one of three potential sites for a nuclear power plant in November 2011.This decision was met with strong opposition from local communities and local governments. On 12 February 2012, more than 94 percent of voters opposed the investment project in a municipal referendum.

The Investor did not conduct any site and environmental assessments at the Gąski site, and eventually formally abandoned it [as a potential NPP site] in 2016.

V.2.1.2.3 Cancellation of Choczewo site and selection of Lubiatowo - Kopalino site in 2016

At the turn of 2013/2014, the first phase of environmental and site studies was performed for two potential sites (Żarnowiec, and Choczewo), which, following verification of preliminary results, showed the high environmental value of the Choczewo site. However, due to the lack of analysis regarding potential impacts on Natura 2000 sites, there were no grounds to abandon this site. Additional analyses conducted at the beginning of 2015 showed the risk of significant impacts on the Natura 2000 site Białogóra PLH220003, therefore the Investor launched activities in 2015 to independently and reliably verify this risk. In parallel to verifying the risk of losing the Choczewo site, the Investor started analyzing the possibility of changing the coastal location. The internal analysis included the area adjacent to the existing location. On the basis of the conducted internal analyses, the Lubiatowo - Kopalino site variant was selected from among the coastal sites previously considered by the Investor.

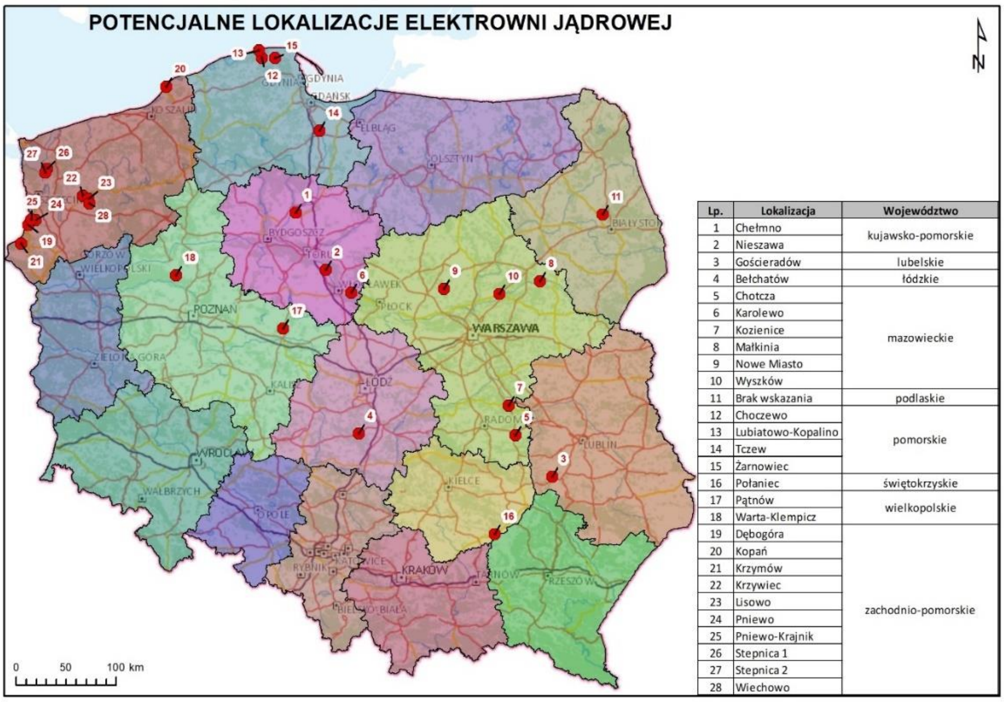


Figure V.2- 4 Potential NPP sites presented in the Polish Nuclear Power Program in 2014.
[Potential NPP sites: Site No., Site name, Voivodeship]

Potencjalne lokalizacje elektrowni jądrowej	Potential NPP sites
Lp.	Site No.
Lokalizacja	Site name
Województwo	Voivodeship

Source: In-house study based on [129]

The Lubiatowo - Kopalino site variant was also identified as one of the three that would allow the use of seawater for open cooling water system in the Polish Nuclear Power Program adopted in January 2014 [Figure V.2- 4].

For the purpose of evaluating the potential Lubiatowo - Kopalino site, a multi-criteria analysis was conducted based on a matrix of technical and organizational criteria. The same set of criteria, and assigned weights and scores was used as in 2011 for PGE's assessment of Choczewo, Żarnowiec, Gąski and other candidate [potential] sites to identify sites for environmental and site studies. A significant methodological difference between the assessment process performed in 2011 and the assessment of the Lubiatowo - Kopalino site is the reliance on purchased archival and administrative data as well as acquired scientific studies, rather than publicly available data, and the performance of data verification in the field. The potential Lubiatowo - Kopalino site received a high score, which confirmed that the choice was justified.

In 2016, the Investor took the following actions based on its own and commissioned research and analysis:

- abandoning the Choczewo site and taking no further action on the first Polish nuclear power plant project at that site,
- selecting the Lubiatowo - Kopalino site as a site variant for the first Polish NPP to undergo detailed studies.

The Choczewo site was abandoned and the Lubiatowo - Kopalino site was selected for the following reasons:

- Hydrogeological conditions

Analysis of the materials obtained from geological survey of the Choczewo, and Lubiatowo - Kopalino sites, and numerical hydrogeological modeling allowed to conclude that the Choczewo site had much more difficult ground and water conditions for deep excavations under dewatering conditions. Despite the technical feasibility of applying methods to reduce the cone of depression, due to the direct vicinity of the site to the Białogóra Natura 2000 site, there is a significant risk that the Project would have a negative impact on the Natura 2000 site at the construction stage (including through the dewatering process), as well as as as a result of the applied mitigation measures (e.g. construction of silt screens).

The Lubiatowo-Kopalino site, on the other hand, is characterized by much more favorable ground and water conditions for excavation of trenches allowing for setting of building structures at the depth of nearly 26 m below the surface level (particularly in its western part). It is conditioned by the occurrence of cohesive formations at the depth of 16 m to 25 m below ground level, which enables the use of protection for the excavation walls (vertical filtration screens, diaphragm walls, etc.) that will effectively protect the excavation against the inflow of groundwater to the bottom, as well as limit the spatial extent of the depression cone and minimize the negative impact of the Project on the environment, including on the Natura 2000 sites.

- Natural conditions

Both sites are located in the coastal dune belt. Both sites have similar natural habitats, dominated by mixed forests and coniferous forests on coastal dunes. White and grey dune habitats can also be recorded at both sites, but at Choczewo site these habitats are locally dominant (area of Wydma Lubiatowska). The main differences between the analyzed sites concern mainly the degree of conservation and natural value, as well as the share of valuable and non-valuable habitats that cover the analyzed areas. It should be emphasized that the Choczewo site is of more natural and economically unused nature (Wydma Lubiatowska) in contrast to the commercial forest managed in most of the area at the Lubiatowo - Kopalino site. At the Choczewo site, areas of high natural value are more scattered over the entire area, in contrast to a large, coherent section of the central-southern and western part of the Lubiatowo-Kopalnio site, where, due to forest management, coniferous forests of low or medium biodiversity dominate. The proportion of white and grey dunes is also much smaller.

- Infrastructure conditions

The conditions for the construction of associated investment projects for the Choczewo, and the Lubiatowo - Kopalino sites are quite similar. It should be noted, however, that due to the possibility of constructing shorter sections of the dedicated power connection and road connection infrastructure, as well as the possibility of routing longer sections thereof outside urban areas, the Lubiatowo - Kopalino site may have an advantage over the Choczewo site in those areas.

- Socio-economic conditions

The Choczewo site has functioned in the consciousness of local communities much longer - since 2011 - than the Lubiatowo - Kopalino site variant identified in 2015. However, local community resistance to the investment at the Choczewo site was much stronger and took organized forms. This may have been due to the fact that landowners in the Choczewo site are primarily "summer vacationers" who live most of their lives, including carrying out their main income-generating activities, elsewhere. In their case, there was practically no space for dialogue and discussions in which the Investor could propose solutions to compensate for the possible decrease in the number of tourists or nuisance associated with the construction and operation of the power plant. Summer vacationers are only interested in maintaining the status quo. The situation was definitely different for the residents of the Lubiatowo - Kopalino site. As permanent residents of the area, they were open to initiatives that would provide them with the opportunity to earn a decent income, and provide their children with opportunities. To that end, they were willing to change or adjust the profile of their existing activities/business operations. Their attitude gave the Investor a much broader opportunity to offer solutions that they consider adequate compensation for the significant interference in their existing lives (jobs, educational opportunities for children, road and municipal infrastructure, etc.).

The Siting and Environmental Study Program launched by the Investor in 2016 was developed in accordance with the requirements of the Decision of the Director General for Environmental Protection of 25 May 2016 (Decision, GDOŚ GDOŚ Decision) [87] for two site variants, i.e. Żarnowiec, and Lubiatowo - Kopalino.

The comparative site analysis considers two potential sites for the NPP - Lubiatowo - Kopalino directly on the Baltic Sea and Żarnowiec about 10 km inland. The sites are shown in the figure [Figure V.2- 5].

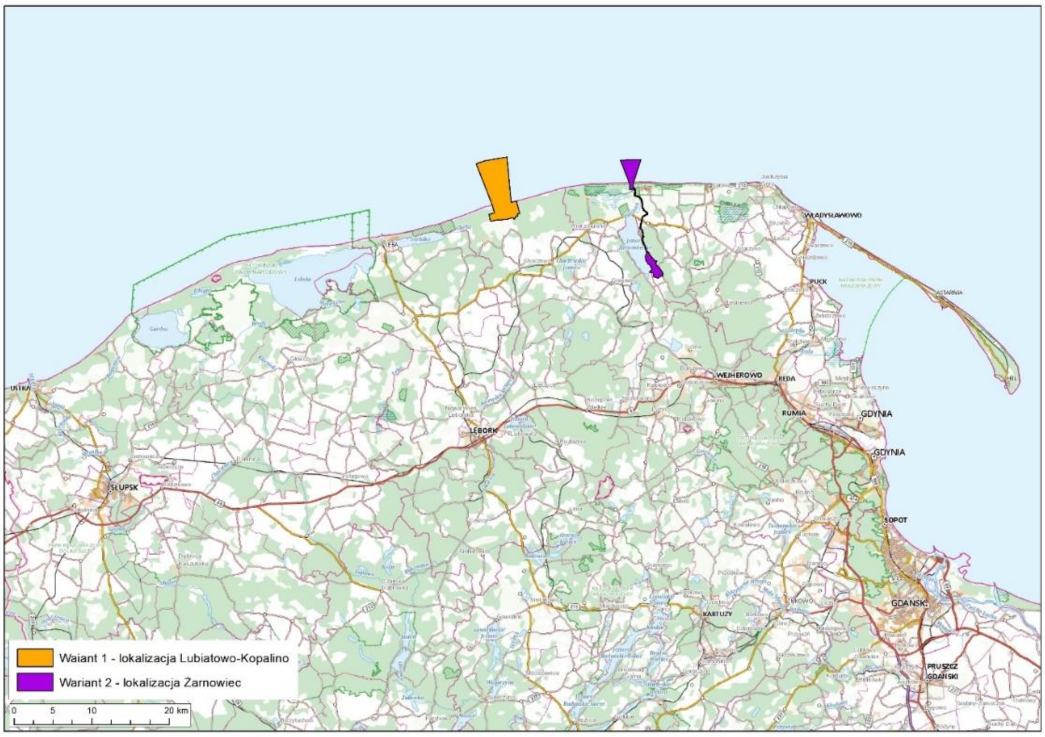


Figure V.2- 5 Lubiatowo - Kopalino, and Żarnowiec sites
[Legend: Orange – Lubiatowo-Kopalino site, Purple – Żarnowiec site]

Source: In-house study

The installations and equipment required for each potential site vary depending on the cooling water system sub-variant considered. A consequence of the differences in installations and equipment are different arrangements for the NPP site. Each such arrangement is referred to as a [technical] sub-variant. The NPP can have a cooling system either in closed circuit with cooling towers or in open circuit using seawater. There are three general sub-variants (closed cooling system at Żarnowiec site, and closed and open cooling system at Lubiatowo - Kopalino site), which can be further subdivided into two cooling options at ŻA and one for open and two for closed cooling system at Lubiatowo - Kopalino site. The sub-variants of the closed cooling system differ in their desalinated water requirements, hence the two closed cooling system options.

V.2.2 Comparative analysis of site variants

V.2.2.1 Comparative Analysis Methodology

The comparative analysis consists of 11 steps [Figure V.2- 6], which are characterized by the following activities:

Stage 1. Defining Objectives.

The first step is to define the objectives of comparative analysis. In this step, the scope of the methodology and its further requirements were established so that it could be considered effective;

Stage 2. Identifying and defining the main criteria to be considered, and the exclusion criteria

In this step, the main criteria are identified and defined to compare the two sites. An example of a primary criterion might include biodiversity, external natural hazards, land/site conditions, etc. These represent complete groups of potential differences that should be considered when making site comparisons. Any international or national exclusion criteria are also identified at this stage. Exclusionary criteria include criteria that, if cannot be met, categorically exclude a potential site from further consideration in the site selection process. These criteria generally address attributes, such as events, phenomena, or hazards, for which there are no practical engineering solutions, and for which it will not be possible to meet relevant regulatory or legal requirements;

Stage 3. Definition of sub-criteria for the main criteria

Each main criterion consists of sub-criteria. The various areas of detailed domains that together form an attribute are criteria. These components are defined so that they can be evaluated and compared based on their own metrics. Examples include seismic among external natural hazards or infrastructure requirements among site area conditions. If further details are required within the criteria to highlight significant scores, a sub-criterion may be used, e.g. seismic criteria are divided into tectonic plate boundaries and active faults;

Stage 4. Identifying metrics of the sub-criteria against which the evaluation will be done

For each of the specified (sub)criteria, the metrics with which they are measured are established. The metrics are flexible to accommodate differences in available data and can even be modified for quantitative or qualitative approaches. For example, a sub-criterion for an industrial plant might be distance from a high-explosive hazard (ATEX) facility or distance from an explosion source transport route. A qualitative measure may be the subjective judgment of the subject-matter expert on the risk to the site posed by a given hazard;

Stage 5. Identify available/required data and any data gaps

Available data and information [4] were reviewed to determine the criteria metrics. If similar and sufficient data are available for both sites, a simple direct comparison of the sites can be made. If there are deficiencies for one or both sites, further actions to be taken are determined. Any information gaps that cannot be filled in the time allotted for the study/survey are also identified;

Stage 6. Determining the basis for scoring

All metrics are rated on a five-point scale, with the least favorable having the greatest impact or posing the greatest challenge to the site, while the most favorable having the least/no impact or posing no challenge. For the explosion hazard example, the metrics are based on distance from the site boundary with the following scoring:

Most adverse - the distance to the nearest listed hazardous industrial facility is less than or equal to 0.5 km from the site;

Adverse - the distance to the nearest listed hazardous industrial facility is greater than 0.5 km but less than or equal to 1 km from the site;

Neutral - the distance to the nearest listed hazardous industrial facility is greater than 1 km but less than or equal to 5 km from the site;

Favorable - the distance to the nearest listed hazardous industrial facility is greater than 5 km but less than or equal to 10 km from the site;

Most favorable - the distance to the nearest listed hazardous industrial facility is greater than 10 km from the site.

This ensures that the analysis developed is appropriately balanced. Justification is based on, among other things, international and national guidelines and applicable laws, examples of similar projects, and expert judgment. In the first stage of evaluation descriptive wording is used. Numerical scores are included after all attributes have been assigned a position on a five-point scale.

The information developed in steps 1-6 is compiled in a methodology report [4] in which the consistency between the different criteria can be assessed and adjusted accordingly;

Stage 7. Evaluation against exclusion criteria

Sites under consideration are evaluated against exclusion criteria specified by Polish law and guidelines, including international guidelines. It can thus be demonstrated that the sites under consideration meet [the requirements under] international guidelines for nuclear facilities. A site/location that meets the requirements is considered for assignment of a score, based on discretionary criteria. As mentioned earlier, the criteria in the exclusionary evaluation are also considered under the discretionary criteria to determine the challenges that these sites themselves pose to a potential NPP;

Stage 8. Assigning scores in terms of discretionary criteria and determination of importance (prioritizing).

This stage includes three activities:

- the scoring of each criterion,
- determining importance (prioritizing) of the criteria for specific areas,
- determining which criteria will be further evaluated.

Assigning scores to criteria Using the basis of evaluation described in Step 6, each criterion is rated on a five-point scale and a justification is given for the score assigned.

If, during score assignment, it is found that the available information is not consistent with the basis for scoring, Step 6 (determining scoring rationale) is repeated. The scoring basis can be reassigned after reviewing the available information.

Significance (importance). Since individual criteria differ in importance, each criterion is considered in relation to the others and an importance factor is assigned. This is done in workshops to ensure that multi-disciplinary expert knowledge is applied. The sequence of importance is defined as follows:

<u>Criteria from high importance areas:</u>

When compared to medium or "neutral" significance with a significance factor of 4, the following classification is used:

- High twice as important as Medium, i.e., an importance factor of 8;
- Very high twice as important as high, i.e. an importance factor of 16.

<u>Criteria from low importance areas:</u>

Compared to medium or "neutral" significance with a significance factor of 4, the following classification is used:

- Low half as important as Medium, i.e., an importance factor of 2;
- Very Low half as important as Low, i.e., an importance factor of 1.

A summary of the scoring and scoring basis provides guidance and sets the context for determining the importance of each criterion. All criteria are initially rated as having an average importance (4) and this rating is then modified.

The scale described above is a non-linear distribution. This allows high disproportionality (up to a factor of 16) between criteria to be considered. It should be noted that there are different approaches to using importance factors that should be considered in the comparative analysis. The proposed method allows for a rational evaluation of the criteria (i.e., one criterion is either equally, twice, or half as important as another). A sensitivity analysis of the importance classification system against linear and logarithmic options showed that the different weighting options do not significantly change the differentiation criteria.

Direct weighting is a simple process with low degree of complexity, but the probability of bias in the results is high. Potential unintended overemphasis on any particular criterion was partially mitigated through rigorous sensitivity testing (c.f. Step 10). Furthermore, the adopted methodologies are most suitable for attributes that are evaluated in the same manner (e.g., quantitatively). The site comparison includes a wide range of scoring criteria, further complicating an already complex methodology. Direct weighting is considered the most appropriate for site comparative analysis because of its low complexity, while partially reducing potential bias through sensitivity testing.

Further assessment. The combination of scoring and importance factors allows to identify criteria that require further evaluation (Step 9). Criteria with a composite score of 16 or higher were included in further evaluation.

Stage 9. Further evaluation to determine the relative impact on the implementation process

The final step of the assessment involves an impact assessment in order to identify potential problems and mitigation measures for each site. The assessment was not conducted for each criterion, but rather focused on those criteria that could have the greatest potential impact on the Project, as described in Step 8. This step also considers sub-variants (closed and open cooling water system) for which some criteria are very sensitive. Similarly, the evaluation focuses on those criteria that are sensitive to site variants;

Stage 10. Interpretation of results.

Documentation of the three-step evaluation (Steps 7, 8, and 9) is compiled to produce a comparative site study. The results of the comparison methodology are only intended to determine which differentiating criteria are important and relevant. The results of the comparison study do not indicate the best variant, but only the most favorable, because there may be differences in the reasons why some criteria are rated higher than others. Therefore, interpretation of the results is completed in order to identify the most relevant differentiating criteria and [to carry out] a more detailed review to indicate the most advantageous option. For this purpose, a sensitivity study is conducted to determine what impact certain criteria may have on the results. Interpretation of results also includes consideration of impact assessment;

Stage 11. Conclusions and recommendations

Based on the interpreted results, conclusions are drawn and possible recommendations are identified.

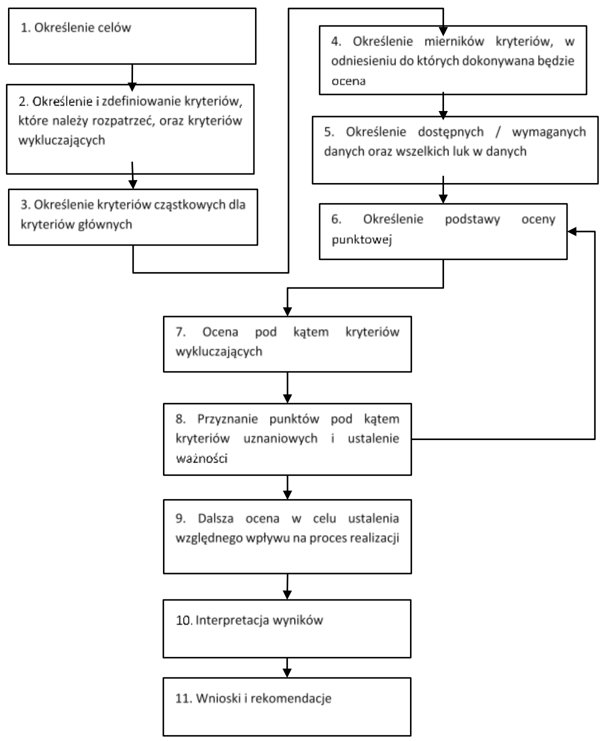


Figure V.2- 6 Stages of the comparative analysis of sites

[1. Goals set, 2. Evaluation criteria and exclusion criteria established and defined, 3. Sub-citeria defined for the main criteria, 4. Criteria metrics established for evaluation, 5. Estblished available/required data together with data gaps, 6. Basis established for points, 7. Review by exclusion criteria, 8. Points and weigths assinged, 9. Further evaluation including possible impact on execution, 10. Interpretation of results, 11. Conclusions and recommendations.]

Source: [4]

V.2.2.2 Determining exclusion criteria

The sites under consideration must meet international and national requirements to be considered viable options for NPP siting. These requirements are the minimum expectations that a site must meet and are the exclusion criteria considered in this study. The exclusion criteria are based on the following sources:

- national sources: siting regulation [108],
- international sources: IAEA Site Survey and Site Selection for Nuclear Installations [43].

Since national and international requirements include similar criteria, all exclusion criteria shall be determined, adopting and justifying, where appropriate, the criteria most difficult to meet. Table [Table V.2- 2] shows all the exclusion criteria from the indicated sources along with the criteria to be adopted for this comparative study.

Table V.2- 2 Identifying exclusion criteria

No.	Criterion	Type	Source	Adopted	Rationale
1	Earthquake Hazard	Within 20 km from the boundary of the planned nuclear facility, in the nuclear facility site's subsoil, there is an active fault or a fault the activation probability of which is higher than once per 10,000 years, and such activation could cause a hazard to the nuclear facility's nuclear safety;	Siting Regulation [108]	✓	The most restrictive exclusion criteria related to earthquake hazards.
2		An earthquake of magnitude 8 EMS-98 has occurred in the site region within the last 10,000 years, or an earthquake of such magnitude is likely to occur more than once every 10,000 years;	Siting Regulation	✓	
3		An earthquake with a probability of occurrence greater than once in 10,000 years and with a magnitude below 8 EMS-98, which will prevent the safe operation of a nuclear facility, is possible;	Siting Regulation	✓	
4		Within the boundaries of the planned nuclear facility site, soils with poor mechanical parameters, including soils of poor load-bearing capacity, swelling properties or other highly disadvantageous parameters for NPP siting, the removal, replacement or reinforcement of which is not possible;	Siting Regulation	✓	
5		Where credible evidence indicates that an active fault may exist at a site that may compromise the safety of the facility, the feasibility of the design, construction, and safe operation of the facility at that site should be reevaluated and, if necessary, an alternative location/site variant, considered.	SSG-9 [42]	x	The Siting Regulation sets out specific criteria that must be met (criteria 1-4). Meeting the Siting Regulation criteria would meet the IAEA's earthquake hazard criteria.
6	Geotechnical issues	In the Site Region there exists a risk that geological phenomena weakening ground stability - such as strong suffosion, karst, rockfall or landslide processes - or any other geodynamic phenomena that might impact nuclear safety of a nuclear facility occur and cannot be compensated for with appropriate structural solutions;	Siting Regulation	✓	All exclusion criteria for geotechnical issues are similar and do not conflict with each other.
7		Slope instability - If it is determined that there is a potential for slope instability that could affect the safety of the nuclear facility, an alternative site should be considered.	SSG-35 [43]	✓	

No.	Criterion	Type	Source	Adopted	Rationale
8		Massive soil liquefaction - The potential for liquefaction of subsurface materials at the planned site should be evaluated using site-specific soil movement parameters and values.	SSG-35	✓	
9		Karst phenomena - if the assessment shows that there is a potential for sinking/collapse, subsidence or uplift of the surface which may affect the safety of the nuclear facility, feasible engineering solutions should be provided, otherwise the site/location should be considered unsuitable.	SSG-35 [43]	✓	
10	Volcanic phenomena	If the results of the assessment indicate that there is a possibility of the following phenomena occurring on or near the site, and their impact on the safety of the nuclear power plant, and that no practical technical solutions are available, the site should be considered unsuitable. ▪ Pyroclastic flows, ejecta and explosions - dynamic physical loads, increased atmospheric pressure, impact of pyroclastic materials, temperatures >300°C, abrasive particles, toxic gases. ▪ Lava flows - dynamic physical loads, floods and stagnant water, temperatures >700°C. ▪ Debris avalanches, landslides, and slope damage/failures. Ground deformation - dynamic physical loads, increased atmospheric pressure, impact of pyroclastic materials, stagnant water, and flooding. ▪ Volcanic debris flows, ash flows and floods - dynamic physical loads, stagnant water and floods, suspended particles. ▪ Opening new eruptive channels - dynamic physical loads, ground deformation, volcanic earthquakes. ▪ Pyroclastic materials - particle impact, static physical loads, abrasive particles in water. ▪ Tsunamis, seiches, crater lake overflow, and glacier rupture - water inundation. ▪ Ground deformation - ground displacement, subsidence or uplift, tilting, landslide. ▪ Hydrothermal systems and groundwater anomalies - thermal water, corrosive water, water pollution, flooding or uplift, hydrothermal alteration, landslides, karst and thermokarst modifications, rapid changes in hydraulic pressure.	SSG-21 [44]	✓	Only discretionary criteria are specified for volcanism. There is no equivalent in the national criteria.

No.	Criterion	Type	Source	Adopted	Rationale
11	Feasibility of an emergency response plan	Proper emergency actions in case of a radiation incident within the nuclear facility will be impossible;	Siting Regulation [108]	✓	The exclusion criteria for the feasibility of the emergency response plan are similar and do not conflict with each other. Therefore, both types of criteria were adopted.
12		If, after an evaluation of the factors identified in Section 6 of IAEA Safety Guide NS-G-3.2 (International Atomic Energy Agency, NS-G-3.2, 2002) and their possible consequences, it is determined that no viable emergency response plan can be established, then such a site should be considered unacceptable.	NS-G-3.2 [41]	✓	
13	Aircraft impact	A civil airport is located within 10 km radius from the planned nuclear facility site, unless the probability for the nuclear facility to be hit by a large passenger aircraft is lower than once every 10 000 000 years.	Siting Regulation [108]	✓	There are no equivalent international criteria, so national criteria were adopted.
14	Flood risk	Flood or inundation risk that may compromise nuclear safety of the nuclear facility is present within the site area and cannot be compensated for with appropriate structural solutions;	Siting Regulation	✓	There are no equivalent international criteria, so national criteria were adopted.
15	Geotechnical phenomena caused by human activity	In the region for which the factor specified in § 2, point 1, letter d) has been considered, within the last 60 years one of the following activities have been conducted: ▪ activities involving the extraction of mineral deposits, or ▪ activities consisting of underground tankless storage of substances or underground waste storage, or ▪ other activity that may compromise nuclear safety of a nuclear facility by inducing seismic shocks, activating fault structures or soil disturbance, sinking or liquefaction of soil, or within the region of the site such activities resulted in occurrence of phenomena that might pose a threat to the nuclear safety during the operation of a nuclear facility.	Siting Regulation	✓	There are no equivalent international criteria, so national criteria were adopted.
16	Industrial area	The following [facilities] are located within the distance enabling to exert negative impact on nuclear safety of the nuclear facility: ▪ A military facility or restricted military area with a protected zone of the restricted area. ▪ Facility that might impact the nuclear facility chemically, biologically or mechanically. ▪ A hydrological device within the meaning of the Water Law Act of 18 July 2001.	Siting Regulation	✓	There are no equivalent international criteria, so national criteria were adopted.

No.	Criterion	Type	Source	Adopted	Rationale
		If such negative impact cannot be compensated for with a structural [design] solution.			
17	Issues not related to nuclear safety	Sufficient and reliable source of cooling water, and potential need for cooling towers.	SSG-35 [43]	✓	There are no equivalent national criteria, so international criteria were adopted.
18		Non-radiological environmental impacts, including: ▪ Heat outlets: water bodies and the atmosphere; ▪ Presence of biologically sensitive areas in the vicinity of the site; ▪ Nature reserves, monuments or tourist sites; ▪ Restrictions imposed by statutory authorities on the following issues: Thermal pollution: • The temperature difference between the condenser cooling water inlet and discharge points. • Effects of condenser water discharges on aquatic organisms. Discharge of chemical pollutants.	SSG-35	✓	There are no equivalent national criteria, so international criteria were adopted.

Source: [4]

V.2.2.3 Definition of assessment criteria

In accordance with the methodology described in V.2.2.1, the following comparative analysis steps were conducted:

- Step 1. Defining Objectives;
- Step 2. Identifying and defining the main criteria to be considered, and the exclusion criteria;
- Step 3. Determining sub-criteria for the main criteria;
- Step 4. Determining sub-criteria's metrics;
- Step 5. Identifying available/required data and any gaps in data.

The results of Stages 1-5 are presented in the appendix [Appendix V.2-1] in the table [Table V.2-1-1]. Assigning scores in terms of discretionary criteria and determining the importance thereof (prioritizing).

This stage comprises three activities:

- the scoring of each criterion,
- determining importance (prioritizing) of the criteria for specific areas,
- determining which criteria will be further evaluated.

One of the goals of comparative analysis is to identify criteria that represent key differences between sites. The unweighted results provide only limited insight into the differences because not all criteria have the same importance for NPP implementation. However, if there are no differences between the scores assigned to sites (criteria that do not differentiate sites), they can be omitted from further analysis [Appendix V.2-1] [Table V.2-1-2]).

V.2.2.3.1 Main differentiating criteria

Each of the main criteria differs in terms of its importance to the implementation of the NPP. Therefore, criteria from each area are considered in turn, and their relative importance to other criteria from other areas is determined so that an importance factor can be assigned.

The sequence of importance is defined as follows:

Main Criteria of High Importance:

When compared to a medium or "neutral" importance with a weight of 4, the following classification is used:

- High twice as important as Medium, i.e. weight 8;
- Very high twice as important as High, i.e. weight 16.

Main criteria of low importance:

When compared to a medium or "neutral" weighted importance, the following classification is used:

- Low half as important as Medium, i.e., an importance factor of 2;
- Very low half as important as Low, i.e., an importance factor of 1.

The scores for each site are multiplied by the importance factor, the difference is then calculated for each sub-criterion between sites to determine the differences. The greater the difference between sites, the greater the influence of criteria on site selection. Those with a total score of 16 or higher are included in further evaluation.

The scores of each site were presented on a five-point scale. In this way, each site is evaluated against the agreed upon sub-criteria to determine how it compares to others. The importance factor considers attributes in the context of gaining approval for construction of a nuclear power plant. To ensure common understanding, the following aspects were considered when assigning importance factors:

- Challenges related to obtaining a license to build a nuclear facility;
- Challenges related to obtaining environmental permits;
- Challenges to the feasibility of the Project, e.g., cost, schedule;
- National legal requirements.

Table [Table V.2- 3] shows the weights assigned to the criteria.

Table V.2- 3 Assigned weights/importance

Main criterion/sub-criterion	**Weight/Importance**
Biodiversity	Very high
Marine and coastal geomorphology	Medium
CO_2 emissions	High
Historic environment	Medium
Air quality	Low
Landscape (and visual impact)	High
Marine environment (water quality)	Very high
Hydrogeology (groundwater)	High
Socio-economic impact	High
Health	Medium
Flood risk	Medium
Noise and vibration	Medium
Land and soil contamination	Low
Electromagnetic field levels and ionizing radiation	Very low
Hydrology	Medium
External natural hazards - seismic	Very high
External natural hazards - meteorological phenomena	High
External natural hazards - floods	Very high
External natural hazards - geological and geomorphological hazards	High
External threats caused by human activity - stationary sources	Low
External threats caused by human activity - mobile sources	Low
Radiological impact - population	High
Radiological impact - meteorology and radiological impact	Medium
Emergency procedures	High
Site condition - Site General Arrangement	High
Site condition - development of the main construction site	Low
Site condition - excavation and foundation pouring	High
Site condition - off-site logistics	Medium
Siting aspects - permanent works	High
Siting aspects	High

Source: [4]

Detailed analysis revealed that the 14 criteria presented in the table [Table V.2- 4] are the key main criteria that differentiate the sites.

Table V.2- 4 Key differentiating criteria

Area	Main criterion	Sub-criterion	Second layer sub-criterion
Environment	Biodiversity	Marine environment	Designated areas for the protection of marine biodiversity
		Terrestrial environment	Designated nature conservation areas
			Habitats
	Health	Human health and quality of life	Effects on human health and quality of life
	Hydrogeology (groundwater)	Groundwater	Conditions that favor groundwater-dependent terrestrial ecosystems
Nuclear issues and other threats	External natural hazards	Flood risk	Inland flooding
Site	Site area condition	Site General Arrangement	Spatial constraints of the site for the construction strategy
			Spatial constraints for site logistics
		Off-site logistics	Access to the site from the sea
	Siting aspects	Siting aspects	Site area ownership
	Siting aspects	Permanent works	Provision of cooling water infrastructure for the project implementation
			No restrictions to planned land development

Source: [4]

V.2.2.3.2 Sensitivity analysis

The adopted weighting scheme is exponential to account for high disproportionality. Alternative linear and logarithmic systems were also used to determine the effect of this system on the identification of differential factors. Table [Table V.2- 5] shows the alternative validity factor system used in the sensitivity analysis.

Table V.2- 5 Alternative system of determining the weight of the main criteria

Significance of the main criteria	Weight by exponential system	Weight by linear system	Weight by logarithmic system
V. small	1	1	0
Low	2	2	0.693
Medium	4	3	1.099
High	8	4	1.386
V. large	16	5	1.609

Source: [4]

Alternative systems were applied to the final weight assignments determined in the previous benchmarking step, and the most differential criteria were reviewed to analyze the differences. Table [Table V.2- 6] shows the results of the factor importance diagrams, with the most differential factors highlighted in green.

Table V.2- 6 The most differential sub-criteria for alternative schemes of factor importance.

Sub-criterion	Exponential	Linear	Logarithmic
Nuclear issues and other hazards - external natural hazards - flooding - inland flooding	48	15	4.828
Site - permanent works - provision of cooling water infrastructure for the project implementation	32	16	5.545
Site - condition of the site - main site development plan - spatial limits of the site for the construction strategy	24	12	4.159
Site - permanent works - site plot flexibility	24	12	4.159
Site - condition of the site - main site development plan - spatial limits for the logistics of the site area	24	12	4.159
Environment - biodiversity - terrestrial environment - designated nature conservation areas	16	5	1.609
Environment - biodiversity - terrestrial environment - habitats	16	5	1.609
Environment - health - human health and life quality - effects on human health and life quality	16	12	4.394
Environment - biodiversity - marine environment - designated marine biodiversity conservation areas	16	5	1.609
NPP alignment issues - condition of the site area - off-site logistics - access to the site from the sea	16	12	4.394
Site - siting aspects - siting aspects - site area ownership	16	8	2.773
Hydrogeology (groundwater) - groundwater - conditions that support groundwater-dependent terrestrial ecosystems	16	8	2.773
Nuclear issues and other hazards - human induced external hazards - stationary sources - industrial plants and their activities	8	8	2.773

Source: [4]

When three weighting factor systems are used, the 10 criteria with the greatest difference are shared. Note that the order differs slightly because in the logarithmic system, cooling water infrastructure is the most differentiating criterion. Criteria for biodiversity meet the requirement of an exponential system for further evaluation, i.e., a score difference of 16 or more. The linear/logarithmic system and the exponential system define 11 common criteria for further evaluation.

Sensitivity analysis is performed on key differentiating criteria that are established as baseline criteria. The importance factors assigned to the criterion areas within the key output criteria are differentiated twice:

- one level up (e.g., from high significance to very high significance), and
- one level down (e.g., from high significance to medium significance).

The variation in weighting factors resulted in two further lists of key criteria for further evaluation. The lists of key criteria are compared to the baseline criteria to assess the sensitivity of the scores. All key criteria lists contain the same criterion for further evaluation. A list with a reduced importance factor results in more criteria receiving the same final score, which is to be expected since many attributes received a high or medium importance factor and none received a very high score.

The key criteria were found to be common to all the scenarios and no new criteria were introduced. Therefore, the results are largely insensitive to the importance/weight coefficients.

The sensitivity analysis conducted showed that the key differentiating criteria are largely insensitive to the assigned weighting factors. Differences in grades are the most influential factor in key differentiating criteria.

Therefore, the key differentiating criteria identified were further evaluated for impacts and mitigation measures [Table V.2- 4].

V.2.2.4 Determination of key differentiating sub-criteria

In stage 9 of the Site comparative analysis methodology, the overall methodology for "further assessment to determine the relative impact on the implementation process" is defined as follows:

- The stage includes an impact assessment to identify potential problems and mitigation measures for each site. The assessment is not conducted for each criterion, but rather will focus on those criteria that could have the greatest potential impact on the project, as described in stage 8. This stage also considers site variants (including closed and open cooling sub-variants) for which some criteria are very sensitive. Similarly, the assessment focuses on those criteria that are sensitive to site variants.
- Stages 2 to 8 of the comparative analysis methodology involved scoring the criteria from each area for each site to identify the key differentiating criteria where the differences between the two sites were greatest and most relevant to site selection. These are:
    - External natural hazards - flooding - inland flooding;
    - Siting aspects - permanent works - provision of cooling water infrastructure for the project implementation;
    - Siting aspects - permanent works - site plot flexibility;
    - Siting aspects - site area ownership;
    - Site condition - off-site logistics - site accessibility by sea;
    - Site condition - site area development plan - spatial site limitation for the construction strategy;
    - Site condition - site area development plan - spatial limitations for site area logistics;
    - Hydrogeology (groundwater) - Groundwater - conditions that support groundwater dependent terrestrial ecosystems;
    - Biodiversity - terrestrial environment - designated nature conservation areas;
    - Biodiversity - terrestrial environment - habitats;
    - Biodiversity - marine environment - designated marine biodiversity conservation areas.

The main purpose of the assessment of mitigating measures is to challenge the results of the discretionary criteria and apply mitigating measures to the key differentiating criteria to approximate the results of the sites. This was used to determine the mitigation measures that may be required at each site, as well as the costs and implications for the Project implementation with the use of these measures.

V.2.2.4.1 Methodology of further assessment

Table [Table V.2- 7] presents the objectives identified for the evaluation of the mitigation measures along with the actions to be taken to achieve them. They were developed as described in the Site Comparison Methodology [4].

Table V.2- 7 Methodology of further assessment

Purpose	Actions anticipated in the methodology of further assessment
1. Verifying that assessment results have been applied consistently at individual sites and attribute criteria	- Discuss key assessment results and scoring criteria for key differentiating criteria. - Review the scoring matrix to understand the rationale for selecting key differentiating criteria.

	Purpose	Actions anticipated in the methodology of further assessment
2.	Confirmation of the potential cumulative impact of low differentiating criteria is not crucial for site comparision	- Evaluation of unweighted and weighted scores for all subcriteria from the discretionary assessment. - Key differentiating criteria, non-key differentiating criteria*, all criteria and criteria grouped thematically aggregated to assess the differences between the sites. * Non-key differentiating criteria include all criteria that were not identified as key criteria.
3.	Identifying mitigation measures for potential impacts associated with key criteria	- Interviews with subject matter experts to identify potential mitigation measures for key criteria.
4.	Qualitative assessment of the costs and impacts of the Project implementation with the use of mitigating measures	- Impact on costs and schedule estimated for key criteria in relation to previous assessments. - Indication of disparities between sites in relation to site condition criteria, i.e., the use of mitigating measures where one site scored lower than the other. - Where multiple mitigation measures were identified for one sub-criterion, the total costs/impacts for the schedule were estimated by assessing the total costs and implications of the Project implementation.
5.	Impact assessment (after applying mitigation measures) for each site	- For the site-related sub-criteria, impacts were assessed with mitigation measures taken into consideration using the original scoring criteria to assess the effectiveness of the mitigation measures relating to disparities between sites.

Source: [4]

It should be noted that the mitigation of the effects of external natural hazards and environmental factors was intended to achieve neutrality between sites, as design mitigation measures would then need to be applied to achieve acceptable levels of safety. Therefore, impacts (after applying mitigation measures) were considered in relation to the criteria under Objective 5 above and the original scoring criteria do not apply to these impacts and neutrality means that mitigation measures acceptable to the developed Project can be achieved at the specific site. Therefore, the original scoring criteria are not reapplied to external natural hazards and environmental factors after the implementation of mitigation measures.

The impact of the mitigation measures on cost and schedule was assessed by reference to similar nuclear power plant projects in Europe and experience from other infrastructure projects relevant to the individual mitigation measures.

V.2.2.4.2 Key assumptions in the methodology of further assessment

Key assumptions made in the assessment:

- It was assumed that a strategy of constructing 2 + 1 units for Lubiatowo-Kopalino and 1+2 units for Żarnowiec would be a feasible mitigation measure that could be applied to key criteria where it could improve the site assessment results;
- Adopted AP1000 technology to be included in the assessment;
- It was assumed that the use of dry coolers was not a feasible mitigation measure;
- It was assumed that the purchase/lease of additional land at the Żarnowiec site would be a feasible mitigation measure that could be applied in relation to key criteria where its could improve the site assessment results;
- Żarnowieckie Lake cannot be the source of cooling water for the power plant in Żarnowiec, therefore the Baltic Sea is the only possible source.

The discretionary attribute criteria and scoring matrix were independently reviewed to confirm that the scoring was applied consistently in relation to the specific sites and attribute criteria, and to understand the rationale for selecting key differentiating criteria.

No discrepancies or inconsistencies were found during this process.

V.2.2.4.3 Potential cumulative impacts

To evaluate potential cumulative impacts that may affect the site comparison, unweighted and weighted results were evaluated as shown in table [Table V.2- 8].

Table V.2- 8 Methodology of scoring results assessment

	Unweighted result			Weighted (exponential) result		
Criteria/topic	**Lubiatowo - Kopalino**	**Żarnowiec**	**Difference**	**Lubiatowo - Kopalino**	**Żarnowiec**	**Difference**
Total (sum of all criteria)	321	290	31	2.125	1963	162
Key criteria	42	28	14	388	340	48
Non-key criteria	282	270	12	1.785	1.751	34
Aggregated by topic						
Environment						
Biodiversity	10	11	-1	160	176	-16
Marine and coastal geomorphology	10	9	1	40	36	4
CO_2 emissions	6	6	0	48	48	0
Historic environment	2	3	-1	8	12	-4
Air quality	29	28	1	58	56	2
Landscape (and visual impact)	2	4	-2	16	32	-16
Marine environment (water quality)	21	21	0	336	336	0
Hydrogeology (groundwater)	9	10	-1	72	80	-8
Socio-economic impact	3	5	-2	12	20	-8
Health	9	9	0	36	36	0
Flood hazard	11	10	1	44	40	4
Noise and vibration	3	2	1	12	8	4
Geology and soils	9	8	1	18	16	2
Electromagnetic field levels and ionizing radiation	3	3	0	3	3	0
Hydrology	43	39	4	172	156	16
Nuclear issues and other hazards						
External natural hazards	50	46	4	568	512	56
External hazards caused by human activity	17	15	2	34	30	4

	Unweighted result			Weighted (exponential) result		
Criteria/topic	**Lubiatowo - Kopalino**	**Żarnowiec**	**Difference**	**Lubiatowo - Kopalino**	**Żarnowiec**	**Difference**
Radiological impact	9	9	0	56	56	0
Emergency procedures	5	5	0	40	40	0
Nuclear power plant alignment issues						
Site area condition	38	24	14	136	86	50
Siting aspects	32	23	9	256	184	72

Cells marked in green indicate which site scored better for each criterion/topic, according to the "difference" columns, where Żarnowiec site scored better than Lubiatowo - Kopalino
Source: [4]

The most important results of the assessment presented in the table [Table V.4-9] are as follows:

- The Lubiatowo - Kopalino location was rated higher than Żarnowiec regarding total criteria (sum of all criteria), key differentiating criteria and non-key differentiating criteria. This means that even when the low differentiating criteria are considered jointly, Lubiatowo - Kopalino is still the most favourable site.
- Lubiatowo - Kopalino scored better than Żarnowiec in 16 of the 21 individual focus areas; the only focus areas in which Żarnowiec scored better than Lubiatowo - Kopalino were biodiversity, historic environment, landscape (and visual impact), hydrogeology and socio-economic impacts.

V.2.2.4.4 Mitigation measures indirectly related to key criteria

The evaluation process identified a number of issues related to mitigation measures that are indirectly related to the key criteria outlined below.

- Earthworks:
  - In the case of the Lubiatowo - Kopalino site, a surplus of material is anticipated (positive earth mass balance);
  - A shortage of material (negative earth mass balance) is anticipated for the Żarnowiec site;
  - Demolition materials from the dismantling of the existing partially constructed power plant at the Żarnowiec site have been excluded from the earth mass balance, but may be reusable;
- Construction drainage - Drainage issues at both sites are similar;
- Service corridor (Żarnowiec site) - during operation, the mitigation measures adopted in relation to to long-term protection of the road and related infrastructure (primarily cooling water pipelines) may have a significant impact on costs;
- Terrestrial biodiversity - protected species was not identified as a key criterion but it should be noted that the cost and schedule impact of mitigation measures is likely to be greater for Żarnowiec than for Lubiatowo - Kopalino.

Potential options for mitigating measures that could affect the current scores for each of the key differentiating criteria were examined and the results of this analysis are presented in the following subsections.

Table [Table V.2- 9] shows the matrix used to assess the impact of the applied mitigation measures on the costs and schedule.

Table V.2- 9 Impact matrix

	Impact on schedule	Negligible (no change)	Minor (1-6 months)	Moderate (6 months to 1 year)	High (1-2 years)	Very high (>2 years)
Impact on costs	Result	1	2	3	4	5
Negligible (<€ 100 thousand)	1	1	2	3	4	5
Low (€100,000 -1 million)	2	2	4	6	8	10
Moderate (€1-10 million)	3	3	6	9	12	15
High (€10-100 million)	4	4	8	12	16	20
Very high (>100 million €)	5	5	10	15	20	25

Source: [4]

The impact on costs and schedule was assessed when more than one mitigation measure was identified for a subcriterion.

In the case of mitigation measures with cumulative impact on the schedule, a qualitative assessment was made of the likely duration of each mitigation measure activity, given the implementation of the Project.

V.2.2.4.5 Summary of adopted mitigation measures

Table [Table V.2- 10] summarizes the cumulative impact of the use of mitigation measures on costs and schedule and differences between sites.

The following conclusions were drawn from the assessment:

- The assessment concluded that the Lubiatowo - Kopalino site consistently scored better than the Żarnowiec site. The results were not affected by the weight applied to each criterion;
- The factors that most differentiate the two sites, that is "provision of cooling water infrastructure" and "land availability", cannot be compensated by any mitigation measures -These criteria include the requirement to run an approximately 10-km service corridor to the Żarnowiec site, which cannot be avoided and will therefore always remain a key factor in site selection;
- A comparison of sites after the adoption of mitigation measures continues to favor the Lubiatowo - Kopalina site;
- The impact of mitigation measures on costs and schedule is higherr for the Zarnowiec site to achieve neutrality between the two sites.

Table V.2- 10 Summary of mitigation measures and differences between sites

Criteria	Impact of mitigating measures		Differences between sites
	Lubiatowo - Kopalino	Żarnowiec	
Coastal and inland flooding	4	16	Neutrality between sites
Provision of infrastructure for cooling water	Limited opportunity for mitigation measures, applies to both sites		L-K site most favorable, ŻA least favorable
No restrictions to planned land development	-	12	Reassessment of the ŻA site from unfavorable to favorable; L-K most favorable
Site area ownership	No mitigating measures identified		L-K site favorable, ŻA unfavorable
Accessibility of the site from the sea	No mitigating measures identified		L-K site still most favorable, ŻA least favorable

Criteria	Impact of mitigating measures		Differences between sites
	Lubiatowo - Kopalino	Żarnowiec	
Spatial limitations of the site area for construction implementation	-	16	Reassessment of the ŻA site from least favorable to unfavorable; L-K favorable
Spatial limitations for site area logistics	-	16	Reassessment of the ŻA site from least favorable to unfavorable; L-K favorable
Conditions favorable to hydrogeology	No mitigating measures have been identified at this stage		No change - L-K site unfavorable, ŻA favorable
Designated nature conservation areas (in terrestrial environment)	12	16	Neutrality between sites
Habitats (terrestrial environment)	3	-	Neutrality between sites
Designated biodiversity conservation areas (in the marine environment)	16	16	Neutrality between sites

L-K - Lubiatowo - Kopalino site
Ża - Żarnowiec site
Source: [4]

V.2.2.5 Summary of comparative analysis, selection of preferred site

The Lubiatowo - Kopalino site has been identified as the preferred location to build Poland's first nuclear power plant. The Project implementation is feasible in both sites, but each site has different challenges that require the adoption of mitigation measures. Significant challenges at the sites under consideration will relate to the conduct of the construction process and, for example, the control of drainage during laying foundations.

The most important differences between the sites that cannot be fully neutralized relate to "provision of infrastructure for cooling water" and "accessibility of the site from the sea", and therefore the sites cannot be offset by mitigation measures. These criteria take into account the requirement to run an approximately 10-km service corridor to the Żarnowiec site, which cannot be avoided and will therefore always remain a key factor in site selection.

The larger area of the Lubiatowo-Kopalino site provides favorable opportunities for a more flexible construction of the NPP, while the smaller area of the Żarnowiec site imposes significant, unfavorable constraints on the NPP construction. Due to the increased flexibility of the Lubiatowo - Kopalino site, there are greater opportunities for additional land use for construction and operation of the three AP1000 blocks. The Lubiatowo - Kopalino site is also preferable in terms of the possibility of using an open cooling system, while the Żarnowiec site is not feasible due to its distance from the Baltic Sea. When considering closed cooling systems in the analyzed sites, Żarnowiec still remains a unfavorable site due to its distance from the sea. In addition, the distance from Żarnowiec site to the coast speaks against this location due to the need to build a water pumping station and about 10 km of pipeline for cooling water supply. Although the length of the offshore pipelines in the intake and outlet tunnels is longer for Lubiatowo - Kopalino, the overall complexity of the installation, including about 10 km of cooling water pipelines, is to the disadvantage of Żarnowiec.

Evaluation of key differences showed that the Lubiatowo - Kopalino site consistently scored better than the Żarnowiec site.

Despite the implementation of measures to mitigate the differences between the sites, the Lubiatowo - Kopalino site still performs better than Żarnowiec. For example, in order to achieve neutrality between sites in the area of cost and schedule, a number of mitigation measures need to be taken at the Żarnowiec site to say that the sites are "similar" that do not need to be taken at the Lubiatowo-Kopalino site.

V.2.3 Multi-criteria analysis

The most commonly used methods in site selection processes for siting nuclear power plants are:

- Performance *matrices*;
- *Multi-criteria analysis (MCA*);
- *Cost-benefit* analysis;
- *Pro/con* analysis.

For the process of indicating the preferred location [4] , the advantages and disadvantages of the mentioned methods were reviewed and multi-criteria analysis was indicated as the most suitable tool because this method is well understood and widely used in nuclear projects. Multi-criteria analysis has been used by the Investor’s Technical Advisor (Jacobs Clean Energy) for site selection, including for the Barakah nuclear power plant in the United Arab Emirates and projects in the United States, including the Clinton site and the Shearon Harris and Levy nuclear power plants. Multi-criteria analysis is indicated for use in nuclear industry guidelines in particular IAEA siting guidelines and by the US Electric Power Research Institute.

For the multi-criteria analysis, the DecisionVue tool was used. The Technical Advisor applied DecisionVue for the entire life cycle of the Project up to decommissioning. DecisionVue is customized software that leverages digital databases and consists of five analytical modules that facilitate a logical, transparent, evaluable process for conducting preferred site selection:

- Define, map, and analyze decision goals and priorities;
- Assess direct and indirect factors that could influence the decision in real time;
- Include social, economic and environmental criteria and metrics, thereby improving and enhancing their applicability in the selection process;
- Scenario testing and analysis, including adaptive planning;
- Create rankings, taking into account critical thresholds and feedback;
- Easily auditable data recording, analysis, and visualization of results;
- A structured approach to testing solutions for future situations and conditions.

Each criterion in DecisionVue is linked to an actual data model for visualization and ease of understanding through an interactive ring hierarchy graphic [Figure V.2- 7]. The tool provides a simple, intuitive representation of the grade assignment and weighting process and is an effective method of communication.

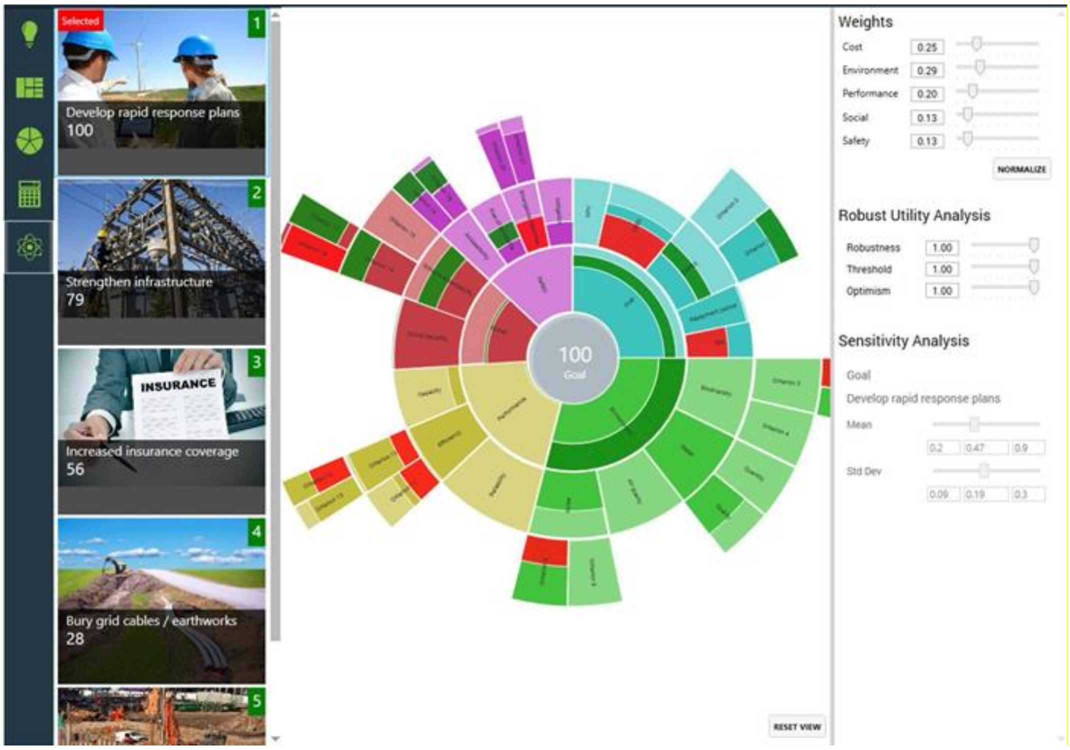


Figure V.2- 7 DecisionVue sunburst chart
Source: [4]

V.2.3.1 A multi-criteria analysis approach

Initially, a number of technical options were developed based on the sites considered and possible NPP configurations. Five sub-variants were subjected to multi-criteria analysis using the DecisionVue tool. Each of the sub-variants was evaluated using the developed criteria. Weights were generated and assigned to the evaluated sub-variants. DecisionVue was used to conduct a sensitivity analysis and check the robustness of the results and determine the sensitivity of the models that could affect the solutions adopted for the Project. At the same time, a number of individual criteria were developed:

- Environmental conditions - include criteria related to biodiversity, marine and coastal geomorphology, climate and carbon emissions, air quality, landscape and spatial aesthetics, seawater quality, socio-economic issues, and noise and vibration;
- Nuclear and other hazard factors - includes criteria related to seismic, meteorologic phenomena, and geologic and geoseismic criteria;
- Site conditions and NPP factors - includes criteria related to site plan, site preparation, excavation, foundations, off-site logistics, permanent works;
- Financial considerations - include criteria related to capital expenditures (CAPEX) and plant efficiency (OPEX).

A weight was assigned for each criterion using an analytical hierarchical process. The method allows simultaneous pairwise comparisons, one criterion against each of the other criteria to rank each criterion against each of the other criteria. This process allows for ongoing consistency assurance checks. The criteria and weights were then digitally processed to create interactive ring charts.

The sub-variants were evaluated against each criterion and then were analyzed using DecisionVue so that a ranking of the considered sub-variants could be produced for sensitivity analysis. The process involved scaling the assigned weights and the resulting scores. Past experience has shown that evidence-based assessments are the most accurate. The sub-variants were also analyzed from the perspective of experience from other projects prepared by the Technical Advisor team.

The assessment of the sub-variants, which is a major part of the methodology, is taken into account in determining the ranking of the sub-variants. The process of the assessment of sub-variants consists of the following elements:

- Identification of sub-variants;
- Definition of minimum requirements;
- Screening analysis of sub-variants;
- Develop and define assessment criteria;
- Develop a scheme for assigning weights to criteria;
- Detailed evaluation of sub-variants using the DecisionVue tool;
- Classification of sites based on sensitivity analysis.

The process of assessing sub-variants is done in stages so that the data being extracted can be taken into account.

In the first stage, the assessment included identification and screening analysis of sub-variants. The goal of this phase was to produce technically and economically feasible solutions. The sub-variants were then analyzed for possible constraints in implementing the Project. The risks associated with not obtaining the necessary permits and approvals, technical and technological constraints, and financial constraints were taken into account. Thus conducted evaluation determined the feasibility of the sub-variants at the locations considered.

The next stage of the analysis involved a detailed assessment of the adopted sub-variants. The sub-variants were then evaluated using multi-criteria analysis.

In the next step, a sensitivity analysis was conducted to verify the results obtained and to identify key areas affecting the identification of the preferred variant.

V.2.3.2 Assessment criteria

Each of the sub-variant was evaluated using the developed criteria. The adopted weights were assigned to the evaluated sub-variants using DecisionVue software to facilitate detailed evaluation. DecisionVue was also used to perform a sensitivity analysis of the criteria and test the "robustness" of the results and determine their sensitivity.

Each criterion was adopted after an extended consultation process through project team meetings. It was critical that each criterion be adequately described, clearly defined, and able to be used to evaluate each of the sub-variant based on modelled data including using a nine-point numerical scale.

Project team members conducted merit, validation, and quality assurance testing. Additionally, in accordance with international best practice guidelines and industry practice, the criteria and sub-criteria were evaluated according to the following principles [18] derived from multi-criteria analysis:

- **Completeness**: have all major criteria been addressed?
- **Redundancy**: have too many criteria been included?
- **Feasibility**: can each of the sub-variants be evaluated against each criterion?
- **Independence of awarding a score to individual sub-variants:** is the score awarded to an individual sub-variant independently awarded and does it not depend on the scores awarded (known during the evaluation) to the other sub-variants?
- **Double counting**: have all criteria that could lead to double counting been removed?
- **Number of criteria** - does the multi-criteria analysis contain an excessive number of criteria that may lead to additional calculations that do not necessarily lead to improved analysis quality?

- **Impacts occurring over time**: has time been included as a direct variable? This can be modelled as a separate criterion with a nonlinear value function.

V.2.3.3 Criteria assessment

The phase consisted of evaluating the score of each sub-variant against each criterion, while presenting possible outcomes and possible consequences for the implementation of the Project. The assessment was conducted using two methods, depending on the type of data available:

- Using results derived from the data you have, based on modelled or real data values (e.g. OPEX presented on a continuous scale such as £10,000/year, £15,000/year, etc.);
- Using values from 1 to 9 (where 1 is the worst score and 9 is the best score) determined by the merit rating and supporting information.

The preliminary results went through several rounds of evaluation to allow potential discrepancies between results to be identified and to eliminate errors highlighted in the results.

V.2.3.4 Criteria weights

A weight was determined for each criterion using analytical hierarchical process. This process uses pairwise comparisons of criteria to assess their importance in a logical and consistent manner.

Examples of pairwise comparisons performed for this activity are shown in table [Table V.2- 11].

Table V.2- 11 AHP Example Pairwise Comparison

Explanation	Assessment
Extremely less important	-9
Definitely less important	-7
Much less important	-5
Moderately less important	-3
Equal importance	1
Moderately greater importance	3
Much greater importance	5
Far greater importance	7
Extreme importance	9

OBSZAR TEMATYCZNY - POZIOM 1 (PREFEROWANY POD KĄTEM ŚRODOWISKA)																		
Pierwsze ograniczenie	Ważniejsze niż								N równym stopniu	Mniej ważne niż								Drugie ograniczenie
Aspekty związane z warunkami lokalizacyjnymi i EJ	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty finansowe
Aspekty związane z warunkami lokalizacyjnymi i EJ	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty środowiskowe
Aspekty finansowe	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty środowiskowe

OBSZAR TEMATYCZNY - POZIOM 1 (OBIEKTYWNA OCENA)																		
Pierwsze ograniczenie	Ważniejsze niż								N równym stopniu	Mniej ważne niż								Drugie ograniczenie
Aspekty związane z warunkami lokalizacyjnymi i EJ	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty finansowe
Aspekty związane z warunkami lokalizacyjnymi i EJ	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty środowiskowe
Aspekty finansowe	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty środowiskowe

OBSZAR TEMATYCZNY - POZIOM 1 (NAJLEPSZA WARTOŚĆ / FINANSE - PREFERENCJA ZAMAWIAJĄCEGO)																		
Pierwsze ograniczenie	Ważniejsze niż								N równym stopniu	Mniej ważne niż								Drugie ograniczenie
Aspekty związane z warunkami lokalizacyjnymi i EJ	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty finansowe
Aspekty związane z warunkami lokalizacyjnymi i EJ	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty środowiskowe
Aspekty finansowe	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Aspekty środowiskowe

Topic Area – Level 1 (Preferred environmental)																		
First boundary	More important								N equal	Less important								Second boundary
NPP siting	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Finance
NPP siting	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Environmental
Finance	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Environmental

Topic Area – Level 1 (Objective assessment)																		
First boundary	More important								N equal	Less important								Second boundary
NPP siting	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Finance
NPP siting	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Environmental
Finance	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Environmental

Topic Area – Level 1 (Best value/Finance – Contracting Authority Preference)																		
First boundary	More important								N equal	Less important								Second boundary
NPP siting	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Finance
NPP siting	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Environmental
Finance	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Environmental

Explanation	Assessment

KRYTERIUM GŁÓWNE - POZIOM 2 - Aspekty środowiskowe																	
Pierwsze ograniczenie	Ważniejsze niż							*N* równym stopniu	Mniej ważne niż								Drugie ograniczenie
Bioróżnorodność	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Geomorfologia morza i wybrzeża
Bioróżnorodność	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Klimat i emisja dwutlenku węgla
Bioróżnorodność	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Jakość powietrza
Bioróżnorodność	9	8	7	6	5	**4**	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Krajobraz i walory wizualne
Bioróżnorodność	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Hydrologia
Bioróżnorodność	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Jakość wody morskiej
Bioróżnorodność	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Uwarunkowania społeczno-gospodarcze
Bioróżnorodność	9	8	7	6	**5**	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Hałas i wibracje
Bioróżnorodność	9	8	7	6	5	**4**	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Poziomy pola elektromagnetycznego i promieniowanie jonizujące
Bioróżnorodność	9	8	7	6	5	**4**	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Geologia i gleby
Bioróżnorodność	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Ryzyko powodziowe
Bioróżnorodność	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Zdrowie ludzkie i jakość życia
Bioróżnorodność	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Hydrologia (wody gruntowe)
Bioróżnorodność	9	8	7	6	5	**4**	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Otoczenie historyczne
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	**2**	1	-2	-3	-4	-5	-6	-7	-8	-9	Klimat i emisja dwutlenku węgla
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Jakość powietrza
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Krajobraz i walory wizualne
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	1	**-2**	-3	-4	-5	-6	-7	-8	-9	Hydrologia
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	1	**-2**	-3	-4	-5	-6	-7	-8	-9	Jakość wody morskiej
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	**2**	1	-2	-3	-4	-5	-6	-7	-8	-9	Uwarunkowania społeczno-gospodarcze
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	**2**	1	-2	-3	-4	-5	-6	-7	-8	-9	Hałas i wibracje
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Poziomy pola elektromagnetycznego i promieniowanie jonizujące
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	**3**	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Geologia i gleby
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Ryzyko powodziowe
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	1	**-2**	-3	-4	-5	-6	-7	-8	-9	Zdrowie ludzkie i jakość życia
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	2	**1**	-2	-3	-4	-5	-6	-7	-8	-9	Hydrologia (wody gruntowe)
Geomorfologia morza i wybrzeża	9	8	7	6	5	4	3	**2**	1	-2	-3	-4	-5	-6	-7	-8	-9	Otoczenie historyczne

Main Criterion – Level 2 (Environmental)																	
First boundary	More important								N equal	Less important							Second boundary
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Marine and coast geomorphology
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Climate and carbon
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Air quality
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Landscape and visual
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Hydrology
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Marine water quality
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Socio-economic
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Noise and vibrations
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Electromagnetic field and ionizing radiation
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Geology and soils
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Flood risk
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Health and quality of life
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Hydrology (ground waters)
Biodiversity	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Historic
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Climate and carbon
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Air quality
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Landscape and visual
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Hydrology
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Marine water quality

Explanation																		Assessment
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Socio-economic
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Noise and vibrations
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Electromagnetic field and ionizing radiation
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Geology and soils
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Flood risk
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Health and quality of life
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Hydrology (ground waters)
Marine and coast geomorphology	9	8	7	6	5	4	3	2	1	-2	-3	-4	-5	-6	-7	-8	-9	Historic

Source: [4]

The weighted scores of the sub-variants against each criterion are then entered into DecisionVue to produce a ranking of the sub-variants, which are then subjected to further sensitivity analysis.

Figure [Figure V.2- 8] provides an outline of the developed criteria and sub-criteria in the form of a tree showing the relation between criteria and sub-criteria. Then there are specific percentage weights, where a higher percentage will mean a higher weight.

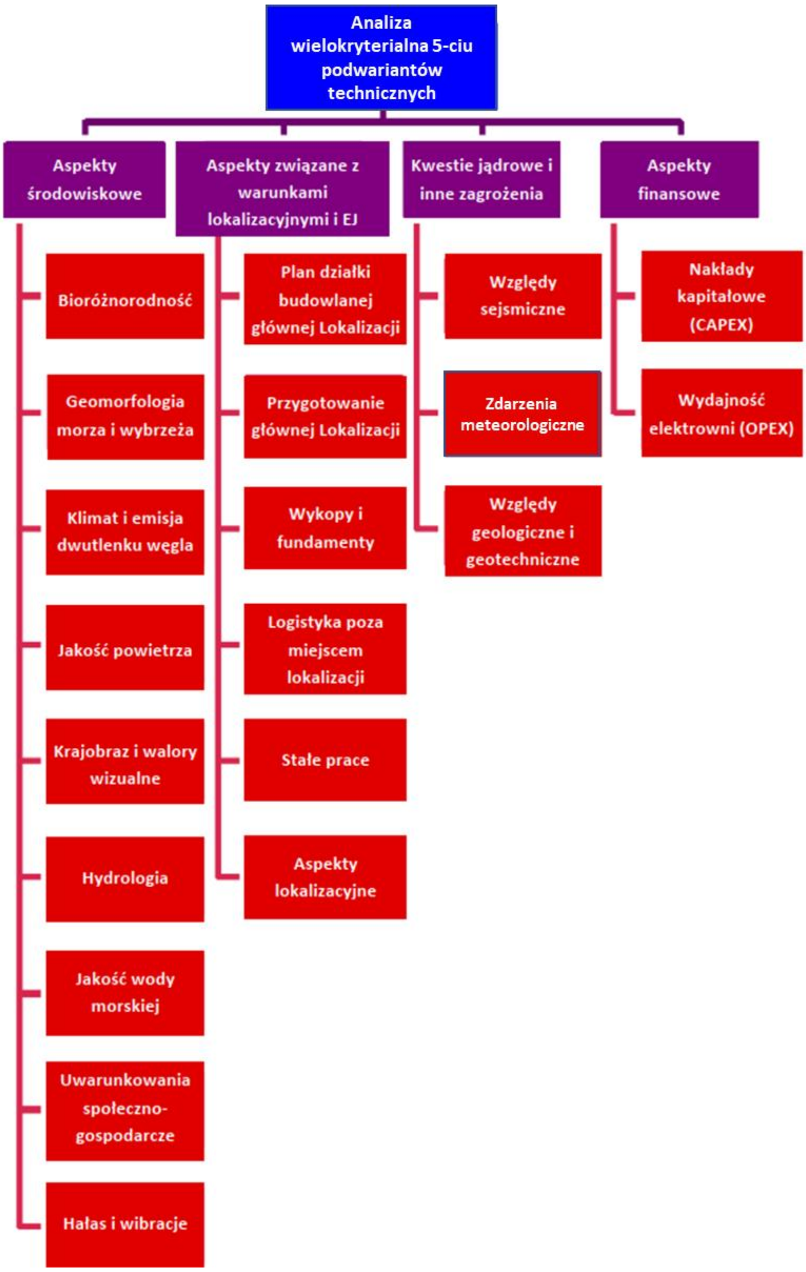


Figure V.2- 8 Developed criteria and sub-criteria showing weightings
Blue field: Multi-criteria analysis of 5 technical sub-variants. Columnes from left to right: Column 1 – Environmental Aspects, Biodiversity, Marine and coastal geomorphology, Climate and CO2 emissions, Air quality, Landscape and visual, hydrology, Marine water quality, Social and economic conditions, Noise and vibration. Column 2 – Aspects of NPP siting conditions, Main site cosntruction, Main site preparation, Excavations and foundations, Offsite logistics, Permanent works, Siting aspects. Column 3 – Nuclear and other hazards, Seismic, Meterological events, Geological and geotechnical. Column 4 – Financial, CAPEX, OPEX.

Source: [4]

An example of a hierarchical ring diagram presenting the relative weight of each criterion is shown in Figure.

The hierarchical ring chart shows the criteria and sub-criteria by color, and the size reflects their importance.

The translations of the graph can be found in the table [Table V.2- 24]

Figure V.2- 9 Example of a hierarchical ring graph generated by DecisionVue.

Source: [4]

In order to avoid conscious or unconscious bias in the process of assessing and weighting of criteria, the evaluation process was divided into two independent and parallel parts:

- **Part 1:** Develop the relative importance of Level 1 and Level 2 criteria;
- **Part 2:** Assign grades for Level 3 criteria for each of the sub-variants.

The results are presented in DecisionVue software to show the final weighted scores obtained by multiplying the weights (expressing the relative importance of the different criteria) by the score of each sub-variant (against the criterion/sub-criterion).

The following table [Table V.2- 12] shows the methodology for evaluating the sub-variants according to the level of criteria.

Table V.2- 12 Evaluation methodology for each level of criteria

Level of criteria	Name	Methodology of assessment
Level 1	Thematic areas of assessment	Part 1: The weight of relative importance
Level 2	Main criteria	
Level 3	Sub-criteria/partial sub-criteria	Part 2: Evidence-based scoring of sub-variants - subject matter experts from DT

Source: [4]

V.2.3.5 Structure and stages of multi-criteria analysis

Stage 1. Identifying and defining the criteria to be considered

A hierarchical process is used to define the criteria. Identify and define general criteria areas against which sub-variants will be compared. General criteria areas may, for example, include biodiversity, external natural hazards, site conditions, etc. Each criteria area contains a set of criteria (main and partial criteria).

Stage 2. Identification of criteria metrics for the assessment

For each of the identified sub-criteria, metrics are identified to assess them. These measures are flexible, allowing for differences in available data, and can be modified for quantitative or qualitative approaches. Where possible, specific, measurable and objectively verifiable indicators will be used to evaluate criteria (e.g. distance to x, cost y), and where this is not possible, a 9-point scale will be used. This will include reference cases (i.e. reasonable best eventuality, reasonable worst eventuality) against which deviations will be compared.

A review of available data and information is conducted to assist in identifying the metrics used for the criteria. This allows us to determine where a direct comparison of sub-variants can be made due to similar or identical assessment techniques and due to the sophistication of the available data. This process can identify data deficits that would require further work or gaps. Their identification is made, and directions for further action are suggested, which by design are built into the preparation of metrics for the criteria.

Volume IV of the EIA Report presents analyses for a number of assessment areas, including noise and vibration, impacts on spatial aesthetics, socio-economic impacts, impacts on the marine environment, etc. These impact analyses considered each of the 5 sub-variants and determined the impact for each phase of the program (from development work through operation to eventual decommissioning). These impact analyses are a key source of data for determining criteria metrics.

Stage 3. Determine the relative importance of each criterion

The relative importance of each criterion was determined using an analytical hierarchical process (AHP). The DecisionVue tool was used to help assign weights to each criterion. Pairwise comparisons were conducted after the metrics for the criteria were defined, allowing the relative importance of the criteria to be determined based on knowledge of what they were intended to quantify.

As part of the weighting stage, a review of the criteria was performed to ensure that the criteria were not mutually exclusive. This resulted in the removal/merging of criteria to prevent double counting of impacts. The weighting evaluation also took into account and corrected any unintended undue emphasis on any particular criterion resulting from the number of sub-criteria assigned to the criterion.

Stage 4. Evaluation against designated criteria

Each criterion is initially scored as described in Step 2, and rationale is provided for the scores assigned by the Technical Advisor's experts in each area. If during the performance evaluation it is found that the available information does not fit the evaluation rules, then it is returned to step 2 and the evaluation rules may be changed to take into account the expanded knowledge of the available information.

Stage 5. Application of weights and sensitivity analysis

The individual results are entered into the DecisionVue tool and predetermined weight ratings are applied. A review of the results associated with the predetermined weights and a series of sensitivity tests are then conducted to confirm the validity of the assigned weights.

In addition to conducting sensitivity analyses, the weightings are adjusted to reflect the priorities of different stakeholders (e.g., the weighting of environmental criteria may be increased and the weighting of cost or schedule-related criteria decreased). This allows us to identify the following variants:

- The best variant in technical and financial terms (variant proposed by the Investor);
- The rational variant, preferable for the environment;
- Rational alternative variant.

V.2.3.6 Areas of research to consider

The objectives of the multi-criteria analysis are defined in this document. To achieve these objectives, the sub-variants must be compared with respect to the areas to be assessed, which are defined by international guidelines and national regulations and expert knowledge of previous or similar nuclear projects. The topic areas are divided into four fields:

- Environmental considerations;
- Site conditions and factors related to the NPP;
- Factors associated with nuclear and other hazards; and
- Financial considerations.

V.2.3.6.1 Environmental conditions, NPP site conditions and factors, factors related to nuclear and other hazards

Environmental criteria were formulated in a comparative analysis to compare locations. The selection of environmental criteria included:

- current knowledge of the sites under consideration and the available level of detail of the Project;
- applicable Polish law (e.g. EIA, water, environmental protection).

The criteria were again reviewed to identify those criteria that affect the differences between the sub-variants and then incorporate them into the multi-criteria analysis. Tables [Table V.2- 13], [Table V.2- 14], [Table V.2-15] show the result of the above analysis.

Table V.2- 13 Screening analysis results of environmental criteria

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
Biodiversity	Areas designated for biodiversity conservation (terrestrial)	Yes	Sensitive to the variant adopted - There are differentiators for both the site and sub-variants that were included in the MCA.
	Legally protected species	Yes	
	Habitats	Yes	
	Areas designated for biodiversity protection (Przybrzeżne wody Bałtyku Special Protection Area of birds (SPA))	Yes	
	Seabed habitats (phytobenthos and zoobenthos)	Yes	

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
Marine and coastal geomorphology	Dune complex	Yes*	Limited sensitivity to the adopted sub-variant
	Features of the seabed		
	Coastal zone processes		
Climate and carbon emissions	Resistance to climate change	Yes*	Limited sensitivity to the adopted variant
	Life cycle carbon dioxide emissions	Yes*	
	Carbon dioxide emissions (policy objective)	No	Insensitive - There are location differentiators for this criterion that were included in the comparative analysis
Historic environment	Not applicable - the attribute has not been transferred	No	Insensitive - There are location differentiators for this criterion that were included in the comparative analysis
Air quality	Air quality impacts on humans and environmental receptors	Yes*	Limited sensitivity to the adopted sub-variant
Landscape and aesthetics of space	Aesthetics of the space	Yes	Sensitive to the adopted sub-variant
	Impact on the landscape		
Hydrology	Impact on aquatic ecosystem	Yes	Sensitive to the adopted sub-variant
Water quality	Heat emissions to water	Yes	Sensitive to the adopted sub-variant
	Increased salinity due to brine discharge	Yes	
	Entrapment, impingement and entrainment of living organisms into cooling water systems	Yes	
	Levels of chemicals used in NPP processes released to marine waters	Yes	
	Levels of cooling water treatment chemicals released to marine waters	Yes	
	Eutrophication	Yes	
	Potential reduction in the status of designated bathing areas	Yes	
	Changes in turbidity levels during construction works	Yes	
	Possible reduction in status of designated WFD / MSFD water bodies	Yes	

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
Hydrogeology	Not applicable - the attribute has not been transferred	No	Insensitive - There are location differentiators for this criterion that were included in the comparative analysis
Socio-economic issues	Employment	Yes*	Limited sensitivity to the adopted variant Differences are generally site-specific (as opposed to sub-variant-specific) and may be adequately captured in the comparative assessment of sites for this criterion
	Tourism and recreation	Yes*	
Health	Not applicable - the attribute has not been transferred	No	Insensitive - There are location differentiators for this criterion that were included in the comparative analysis
Flood hazard	Not applicable - the attribute has not been transferred	No	Insensitive - There are site differentiators for this criterion that were included in the comparative analysis
Noise and vibration	Change in noise levels - traffic	Yes*	Limited sensitivity to the adopted sub-variant
	Change in noise levels - railroad traffic	Yes*	
	Change in noise levels - NPP operation	Yes*	
Geology and soils	Not applicable - the attribute has not been transferred	No	Insensitive - There are site differentiators for this criterion that were included in the comparative analysis
EMF and ionizing radiation	Not applicable - the attribute has not been transferred	No	Insensitive - There are site differentiators for this criterion that were included in the comparative analysis

Source: [3]

Table V.2- 14 Screening analysis results of site conditions

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
Site development plan	Implementation of the construction of a specific variant of the cooling system in the land part	Yes	*Site space constraints affecting the construction strategy*, this sub-criterion was revised to focus specifically on the land-based components of the cooling system variant. It includes the evaluation of construction elements of components such as cooling water channels, cooling towers, desalination station. Spatial impacts on the site as a whole under each variant were also analysed.
	Strategy for building a specific cooling system	Initially not included in the	A new sub-criterion that evaluates the offshore infrastructure construction strategy for each of

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
	variant in the offshore part	comparative site analysis	the cooling water variants. The main measure for this sub-criterion will be the differences in construction methods for each cooling variant due to the diameter and length of the tunnels, number of tunnels, and water intake structure.
	Additional site logistics requirements for the cooling system variant	Yes	*Site spatial constraints affecting site logistics*, this sub-criterion has been revised to focus specifically on additional site logistics requirements in addition to the construction of the nuclear island and other power plant facilities (Balance of Plant), specified for each cooling system variant. In this sub-criterion, additional roadways, office and support facilities requirements, road and rail facilities at the location, concrete plants, precast concrete segment production (PCC) facilities, waste disposal, and additional bulk shipments of materials will be analysed. The term "onsite" is defined as "within the development boundaries of the site," while activities outside of that area are not analysed and are referred to as "off-site."
Site preparation	Site cleanup	No	Site cleanup is not considered a differentiator between cooling system variants. The same site cleanup is required regardless of the variant selected - There are site differentiators for this criterion that were included in the comparative analysis
	Additional site preparation activities for the cooling systems variant	Yes*	*Preparatory works*, this sub-criterion has been revised to focus specifically on preparatory activities at the site related to cooling systems. The analysis will include the magnitude and risk of additional activities needed to begin construction of a specific cooling system variant. These may include construction of a TBM launch shaft, dry dock preparation, desalination block assembly locations, establishment of custom precast segment manufacturing facilities, or concrete plants.
	Provide additional temporary utilities/services	Yes*	*Provision of Temporary Utilities and Services for Project* Delivery, this sub-criterion has been revised to focus specifically on the provision of additional temporary utilities and services required for the construction of each cooling system variant. There is limited sensitivity to the variant adopted. The analysis will include volumes of additional electricity, water, communications, and stormwater drainage, as well as the risks associated with providing them.

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
Excavation and Foundations	Execution of earthworks	Yes	The analysis focuses on earthwork balance, volume of material transported multiplied by distance traveled, material transport routes, storage locations, earthwork stages, and earthwork methodology for each cooling system variant. It also takes into account whether the earthwork required for a particular cooling system variant can be completed within the proposed construction schedule.
	Temporary works	Yes	The analysis focuses on the magnitude and complexity of the required temporary work associated with each cooling system variant. Temporary work considered includes excavation retention, drainage, and contamination prevention.
	Excavations and foundations outside the nuclear island	Yes	The analysis focuses on the excavation and foundations required for each of the cooling system variants. Criteria also include the size and complexity of the soil reinforcement required.
Offsite Logistics	Source to Site	No	Not carried forward, due to the lack of significant factors specific for the sub-variant not previously analysed in the Site Comparison Study.
	Site availability	No	All modes of transportation will generally be required for site preparation, so site availability by road, rail, and sea is not considered a differentiator between the sub-variants. There are, however, site distinguishers for this criterion that are included in the SCS.
Permanent works	Transmission of electricity from a site	No	Power transmission will generally be required for site preparation and is not considered a differentiator between sub-variants. There are, however, site distinguishers for this criterion that are included in the SCS.
	Impacts associated with NPP efficiency/operation	No	The NPP efficiency/operation impacts were replaced by an OPEX and CAPEX criterion that identified differences between the sub-variants.
	Area for approximately 3000 MW	No	It was shown that all the plots would accommodate infrastructure for about 3000 MW.
	Provision of cooling water (CW) infrastructure	No	This criterion was replaced by the MCA analysis.
Siting factors	Easements	No	The variants do not include elements that would affect easements; this is not considered a differentiator between the sub-variants. There are, however, site distinguishers for this criterion that are included in the SCS.
	Permits	No	Permits are not an appropriate category of conditionality as part of the MCA analysis. There

Area	Main criterion	Moved to multi-criteria analysis	Additional Notes
			are, however, site distinguishers for this criterion that are included in the SCS.
	Local and national permits	No	There may be differences in the permits required for different sub-variants, however, compared to the total number of permits required, any distinguishers are too small to be considered. This criterion was not carried forward into the multi-criteria analysis.
	Decommissioning	Yes*	Limited analysis of the complexity associated with the elimination of sub-variants. This criterion implies that the site must be restored to its pre-construction condition.
	Site ownership	No	The land required for the NPP will need to be acquired in order to build it; the choice of the cooling variant will not affect this. Hence, site ownership is not considered a differentiator between variants. There are, however, site distinguishers for this criterion that are included in the SCS.

Source: [4]

Table V.2- 15 Results of the screening analysis of criteria related to site conditions

Criteria	Sub-riteria	Moved to MCA	Additional Notes
External natural hazards	Seismicity	Yes*	Potentially sensitive to the variant
	Meteorological	Yes*	Limited sensitivity to the adopted variant There are limited site distinguishers for meteorological hazards considered in the comparative analysis. The implementation of cooling variants in different sub-variants is sensitive to air temperature.
	Flooding	No	There are site distinguishers for flood hazards that are considered in the comparative analysis. The differences between the sub-variants do not change this threat.
	Geological and geotechnical	Yes	Sensitive to the variant adopted.
External Human Induced Hazards	Stationary hazards	No	There are limited site distinguishers for these hazards that are considered in the comparative analysis. The differences between the sub-variants do not change this threat.
	Mobile Threats	No	There are limited site distinguishers for these hazards that are considered in the comparative analysis. The differences between the sub-variants do not change this threat.
Radiological impact	Meteorological and radiological impacts	No	Insensitive - There are site distinguishers for radiological impact that are considered in the comparative analysis.
	Population		

Criteria	Sub-riteria	Moved to MCA	Additional Notes
Emergency plan	Emergency plan	No	Emergency planning is not related to sub-variants.

Source: [4]

V.2.3.6.2 Financial considerations

CAPEX - This area refers to the factors that affect the capital expenditures (CAPEX) associated with a given cooling water system. CAPEX is the money that will be spent on the acquisition, construction and commissioning of the fixed assets of the various sub-variants, such as cooling towers, desalination plant or infrastructure in the offshore section. The CAPEX amount will be different for each sub-variant and is therefore a distinguisher between them.

OPEX - This area refers to the factors that affect the operating expenses (OPEX) associated with the given cooling water system. OPEX costs are the ongoing expenses that are inherent in the operation of the assets in the given sub-variants, such as cooling towers, desalination plant and infrastructure in the offshore area. The OPEX amount will be different for each sub-variant and is therefore a differentiator between them.

Criteria related to CAPEX/OPEX are included in the table [Table V.2- 16].

Table V.2- 16 CAPEX and OPEX criteria

Area	Main criterion	Additional Comments
CAPEX	Quantities of concrete and reinforcing steel	Generally, more concrete and reinforcing materials needed to construct the variant will increase the cost of direct and indirect construction works, e.g. significantly more concrete and reinforcing steel is required in cooling towers compared to open cooling forebays.
	Features limiting the operational period	They take into account the anticipated operational life of the NPP and any replacement requirements for major equipment (cooling tower, desalination plant equipment, large pumps associated with the cooling system) of the cooling variant over the 60-year operating life of the NPP.
	Commissioning Effort	Assessment of the complexity of the Mechanical, Electrical, Instrumentation, Control, Automation and Process associated with each of the cooling water variants. Specifically, with respect to the complexity of the start-up and commissioning of each sub-variant.
Power Plant Performance (OPEX)	Net Electrical Output	It considers the operational cost impact of each cooling variant in terms of power consumption and effect on net electricity supply to the grid.
	The availability factor (a factor related to day-to-day operations)	Any differences between the cooling variants in terms of the NPP availability factor were analysed (e.g., whether the NPP operations should be suspended during the summer months due to high sea/air temperatures).
	Consumption of bulk chemicals	This criterion takes into account the bulk quantities of chemicals required to operate each cooling variant.
	Number of employees during operation	This criterion takes into account the differences between the number of workers during the operation of specific cooling variants.

Source: [4]

V.2.3.7 Weights assigned

Level 1 criteria weights

The weights obtained for the Level 1 criteria (assessment study areas) are summarised in table [Table V.2- 17] Two different perspectives were applied to determine the best variant in technical and financial categories (also referred to as the Investor's preferred variant), and the environmentally preferable rational variant.

Table V.2- 17 Weights obtained for the Level 1 criteria (assessment study areas)

Perspective	Environmental and socio-economic considerations	Aspects related to site conditions and the NPP	Financial considerations	Total
Investor's preferred variant	20%	20%	60%	100%
Environmentally preferable rational variant	60%	20%	20%	100%

Source: [4]

Level 2 criteria weights

The importance of the Level 2 criteria (attributes) was developed using the same approach, and the weights are included in tables [Table V.2- 18] and [Table V.2- 19], respectively, for each Level 2 criterion (assessment study areas).

Table V.2- 18 Weights obtained for the Level 2 criteria (areas) - Environmental and socio-economic aspects

Main criterion	Weight
Biodiversity	13.19%
Marine and coastal geomorphology	6.48%
Climate and carbon	3.29%
Air quality	5.41%
Landscape and visual	4.27%
Hydrology	11.91%
Marine Water quality	13.05%
Socio-economics	6.38%
Noise and vibration	3.30%
Electromagnetic Field Levels and Ionising Radiation	2.62%
Geology and Soil	4.69%
Flood risk	7.21%
Human health and quality of life	7.64%
Hydrology (groundwater)	7.82%
Historic environment	2.74%
Total	100%

Source: [4]

The compliance factor obtained by weighting the Level 2 criteria for the environmental and socio-economic aspects was 7%, which is less than the upper limit of the compliance factor of 10%, according to the best practice of multi-criteria analysis (MCDA) contained in the report [18].

Table V.2- 19 Weights obtained for the Level 2 criteria (areas) - Aspects related to site and technical conditions of the NPP

Main criterion	Weight
Site General Arrangement	9.08%
Site preparation	7.49%
Excavations and Foundations	32.08%

Main criterion	Weight
Off-site logistics	7.48%
Permanent works	17.42%
Siting aspects	10.24%
Licensing	7.60%
Local and national permits	6.47%
Decommissioning	2.14%
Total	100%

Source: [4]

The compliance factor obtained by weighting the Level 2 criteria on aspects related to the site and technical conditions of the NPP was 4%, which is less than the upper limit of the compliance factor of 10%, according to the best practice of multi-criteria analysis (MCDA) included in the report [18].

Level 3 criteria weights

The weights within each Level 3 criterion (sub-criteria) were assumed to be of equivalent importance within the context of the specific attribute. Thus, each of the two sub-criteria of an attribute (e.g., landscape effects and visual effects) would be weighted as 50% (i.e., 1/2 of the total attribute weight), whereas for an attribute with four sub-criteria (e.g., off-site logistics), each sub-criterion would be weighted as 25% (i.e., 1/4 of the total attribute weight).

CAPEX and OPEX weights

Due to the fact that there are only two attributes for the financial aspects, it is not possible to perform a best-practice pairwise comparison. The weighting of CAPEX and OPEX shown below reflects the fact that, averaged over the operational life of the facility, CAPEX for the Project represent approximately half of the remaining annual cost elements. In addition, the OPEX criteria were divided into one criterion related to annual operating costs and two criteria related to annual revenues (net electrical output and availability factor). Considering them together, the relative weight of CAPEX versus OPEX is estimated to be 10:90, and within OPEX the relative weight of annual operating expenses versus net electrical output and availability factor is estimated to be 20:40:40.

Table V.2- 20 Weights obtained for Level 2 criteria (areas). Financial aspects

Main criterion	Weight
CAPEX	10%
OPEX	90%
Total	100%

Source: [4]

Table V.2- 21 Weights obtained for Level 3 criteria (sub-criteria) - Operating Expenses (OPEX)

OPEX sub-criteria	Weight
Net Electrical Output	40%
Availability factor	40%
Annual OPEX	20%
Total	100%

Source: [4]

Total weights

Total weights for: “Investor’s preferred variant" and "Environmentally preferable rational variant" are presented below

Translations of the diagram can be found in Table [Table V.2- 24]
Figure V.2-10 Pie chart of the criteria weights: technically and financially best variant (variant proposed by the Investor) (top) and environmentally preferable rational variant (bottom).
Source: [4]

V.2.3.8 Results of multi-criteria analysis

V.2.3.8.1 Environmentally preferable rational variant

The environmental performance results are shown in table [Table V.2- 22].

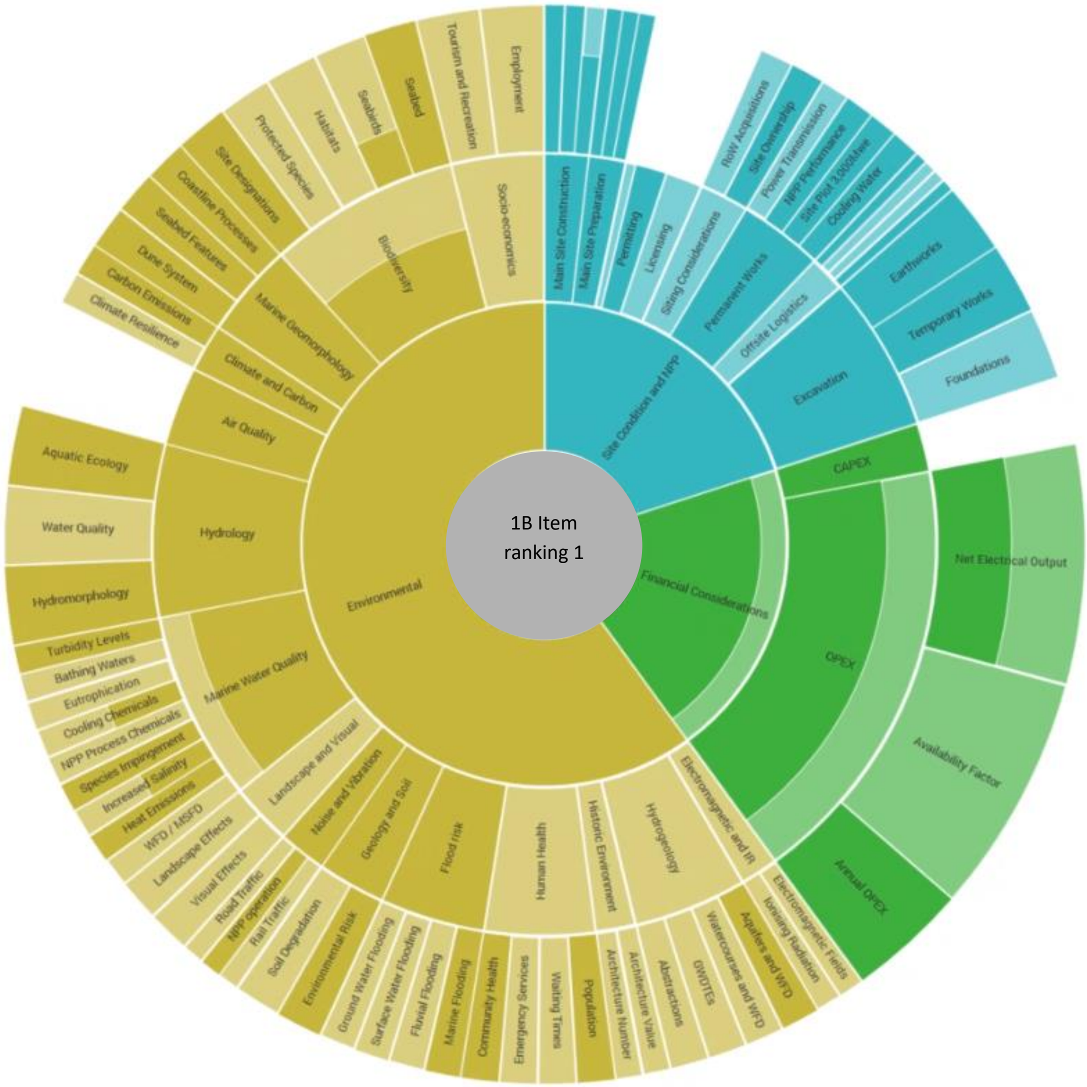
Table V.2- 22 Results of multi-criteria analysis, perspective of the environmentally preferable rational variant

Sub-variant	Environmentally preferable rational variant	Item ranking
Variant 1A - L-K - open cooling system using seawater	99	2
Variant 1B - L-K - closed cooling system (brackish water) using seawater	100	1
Variant 1C - L-K - closed cooling system using desalinated water	35	4
Variant 2A - ŻA - closed cooling system (brackish water) using seawater	65	3
Variant 2B - ŻA - closed cooling system using desalinated water	0	5

Source: [4]

V.2.3.8.1.1 Ranking of sub-variants

The analysis showed that sub-variants 1A [Figure V.2- 12] and 1B Figure V.2- 11] score best in environmental terms, with sub-variant 1B having slightly better overall environmental performance. This is mainly due to the lower impact of the closed cooling system sub-variant on seawater quality due to less water intake, and lower total heat loads in the cooling water discharged. Sub-variants 1C [Figure V.2- 14] and 2B [Figure V.2- 15] are sub-variants with the lowest score for each site due to higher power consumption, larger loads of chemical substances, and salinity of discharges to the marine environment. Sub-variant 2A performs well on a number of criteria. However, as stated in [Chapter V.2.2], Variant 1 - Lubiatowo - Kopalino site is superior to Variant 2 - Żarnowiec site in corresponding sub-variants in terms of a number of criteria.



Partially shaded criterion - score between the highest and the lowest

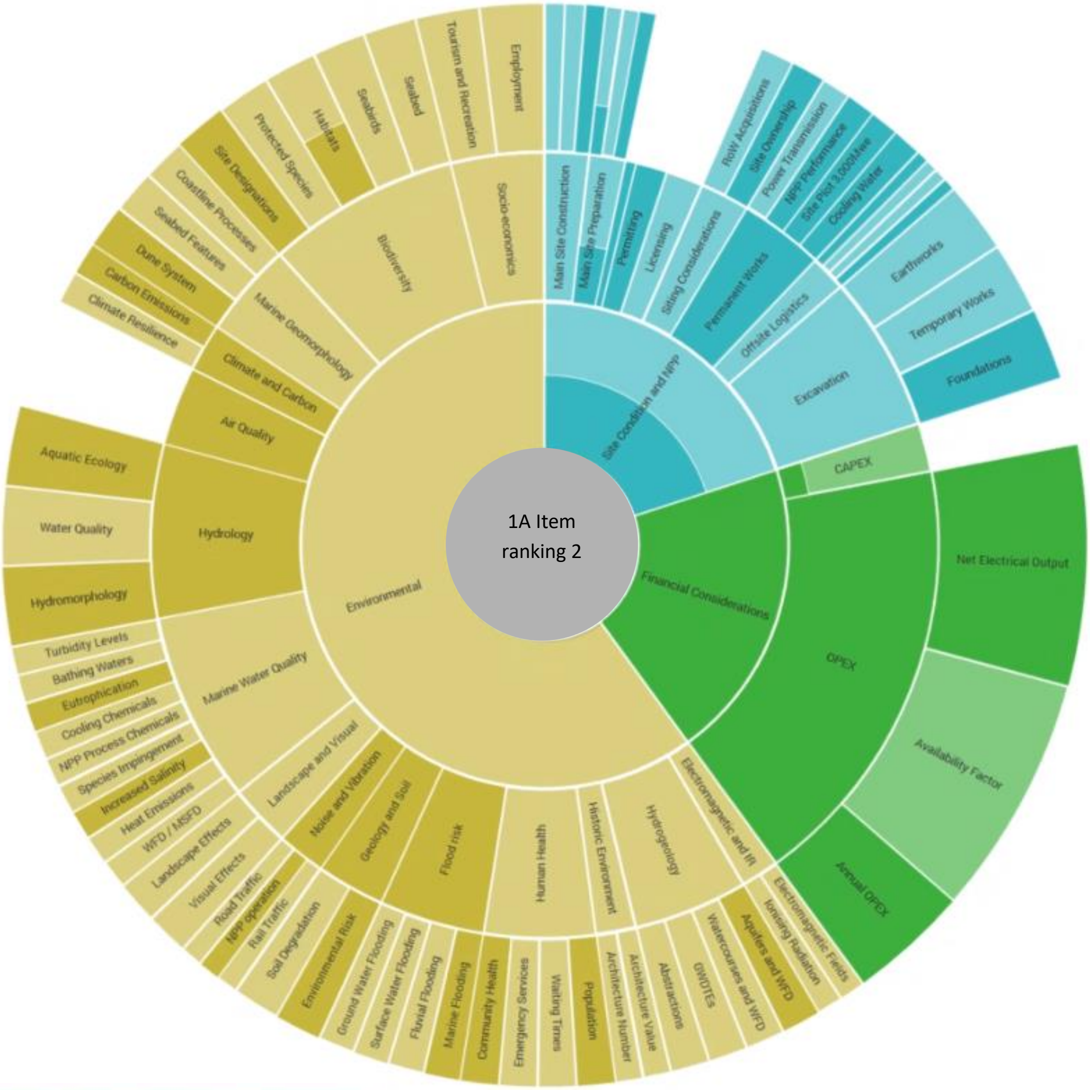
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 11 Sunburst chart of the results obtained from DecisionVue – perspective Environmentally preferable rational variant - Item 1: Sub-variant 1B

Source: [4]



Partially shaded criterion - score between the highest and the lowest

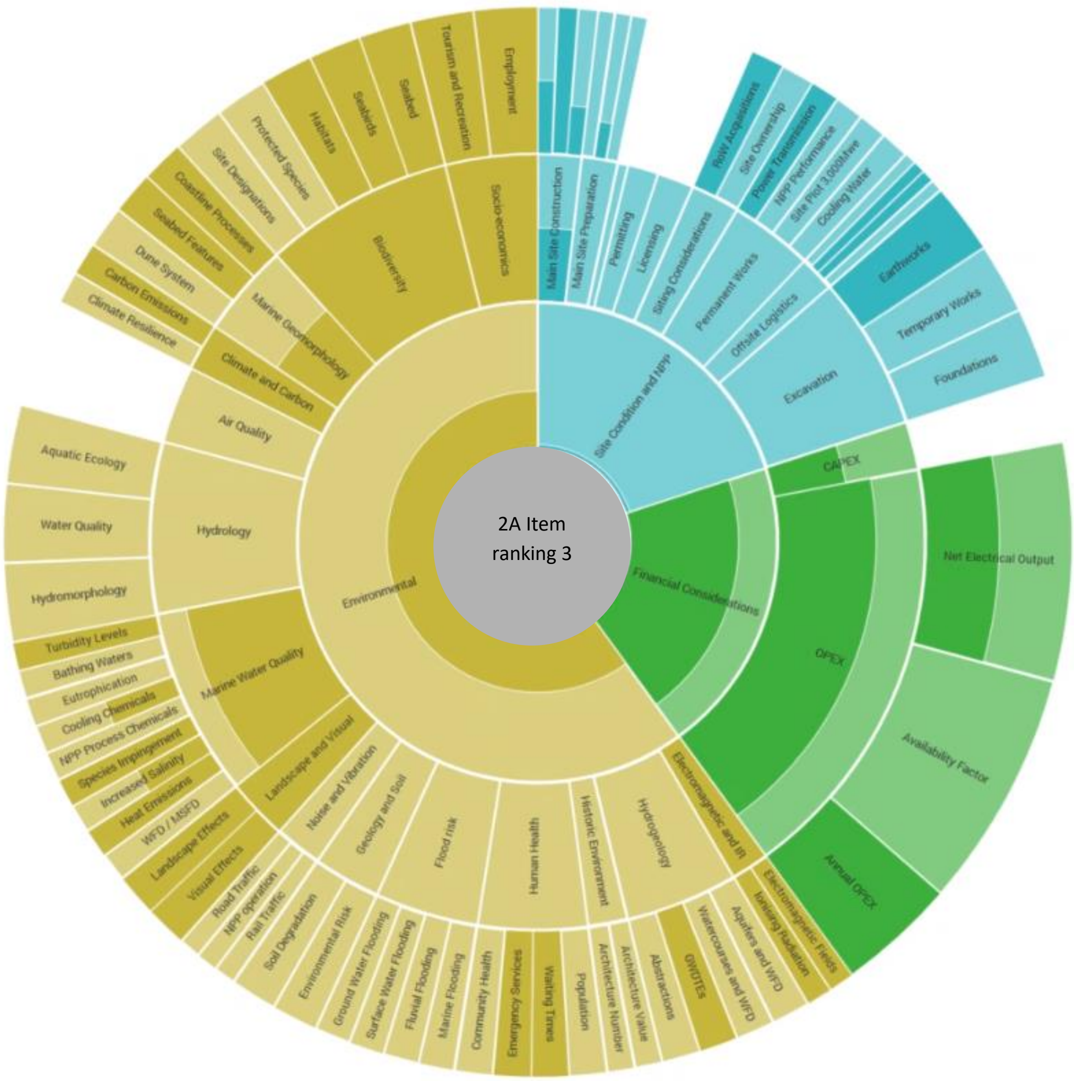
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 12 Sunburst chart of the results obtained from DecisionVue - perspective Environmentally preferable rational variant - Item 2: Sub-variant 1A

Source: [4]



Partially shaded criterion - score between the highest and the lowest

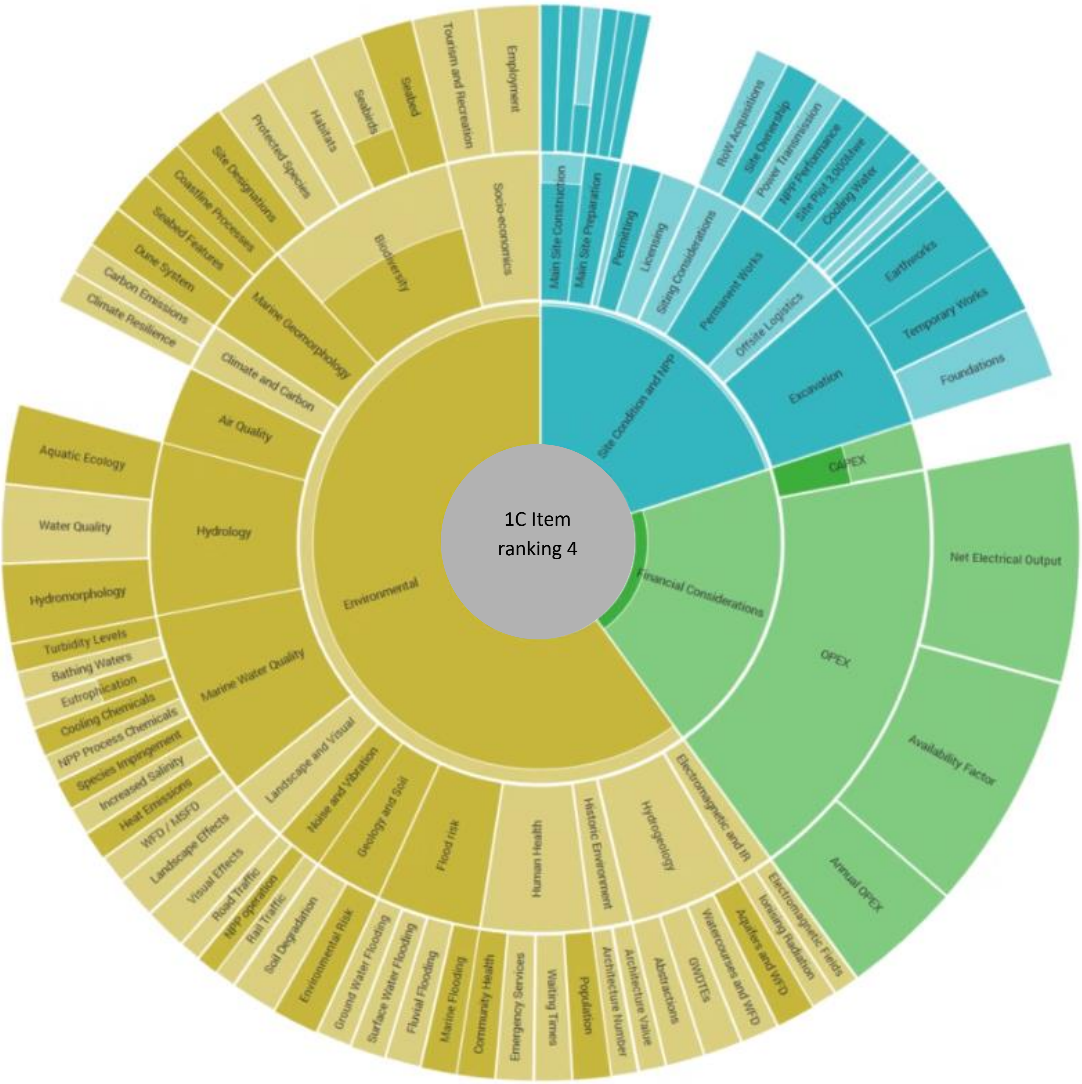
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 13 Sunburst chart of the results obtained from DecisionVue - perspective Environmentally preferable rational variant - Item 3: Sub-variant 2A

Source: [4]



Partially shaded criterion - score between the highest and the lowest

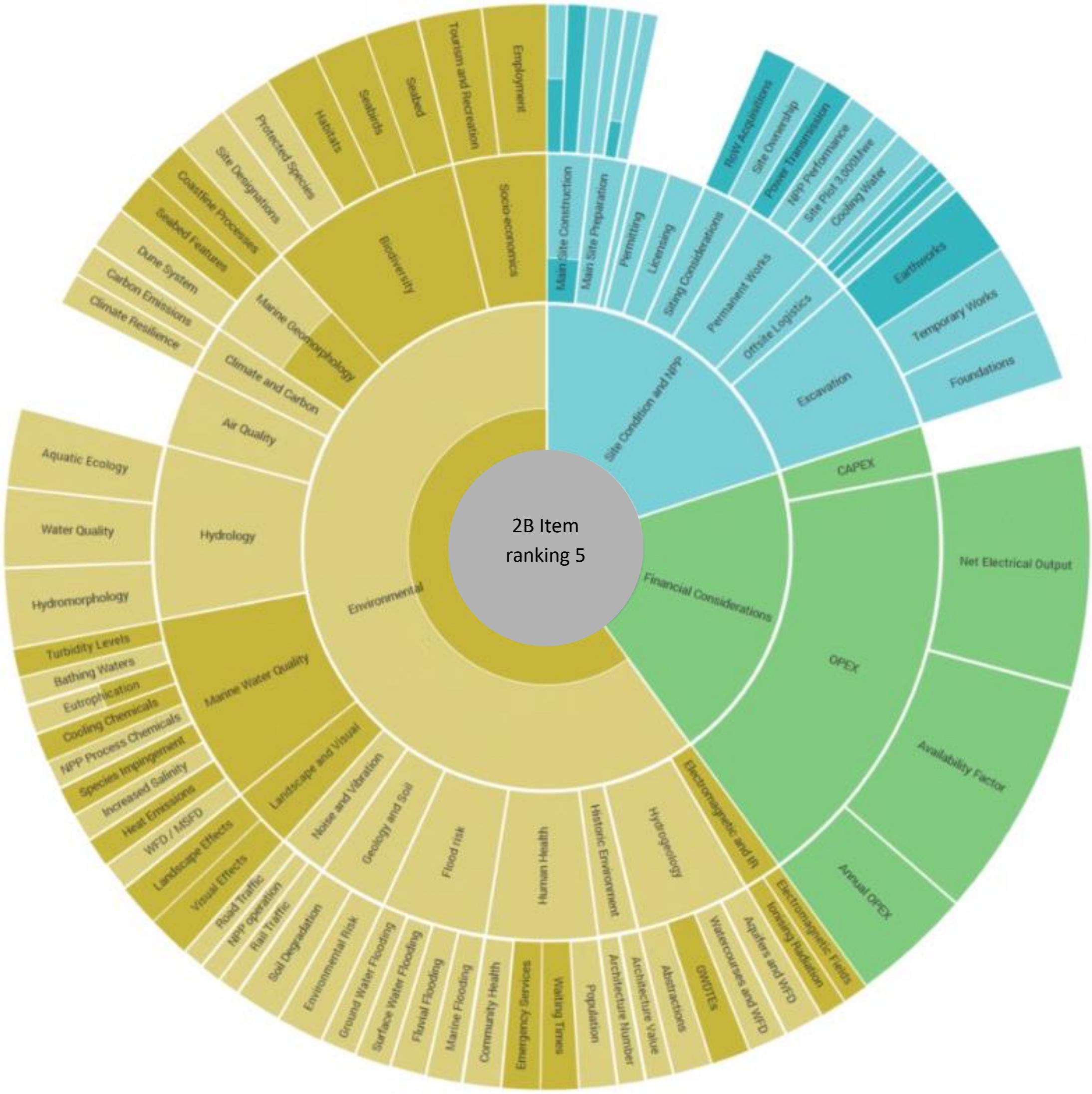
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 14 Sunburst chart of the results obtained from DecisionVue - perspective Environmentally preferable rational variant - Item 4: Sub-variant 1C

Source: [4]



Partially shaded criterion - score between the highest and the lowest

Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 15 Sunburst chart of the results obtained from DecisionVue - perspective Environmentally preferable rational variant - Item 5: Sub-variant 2B

Source: [4]

V.2.3.8.1.2 Sensitivity analysis

Given the similar results for sub-variants 1A and 1B, a sensitivity analysis was performed considering factors that might change individual results relative to the criteria, or the weights between criteria.

Throughout the analysis, it was assumed that the cooling water infrastructure would be constructed using the immersed tube /open trench method. Based on research, this construction method is believed to have a greater environmental impact than other tunneling techniques. It was therefore considered whether an alternative construction technique would change the relative scores of sub-variants 1A and 1B. However, an analysis of the key differentiators between the sub-variants has shown that it is the impact during the operational phase, not the construction phase, that leads to the key differences between the two sub-variants and that these will not be altered by changing the design assumptions.

According to the sensitivity analysis, environmental performance scores depend on the weights used, and sub-variant 1A scores best on a number of criteria that received low weights. However, these criteria are related to some of the most obvious impacts of the Project (e.g., visual amenities, construction traffic, and noise). As a result, these criteria may be considered more important by members of the public, leading to the greater acceptability of sub-variant 1A in relation to sub-variant 1B.

V.2.3.8.2 Investor's preferred variant

The results are shown in the table [Table V.2- 23].

Tabela V.2- 23 Results of multi-criteria analysis, perspective - Investor’s preferred variant

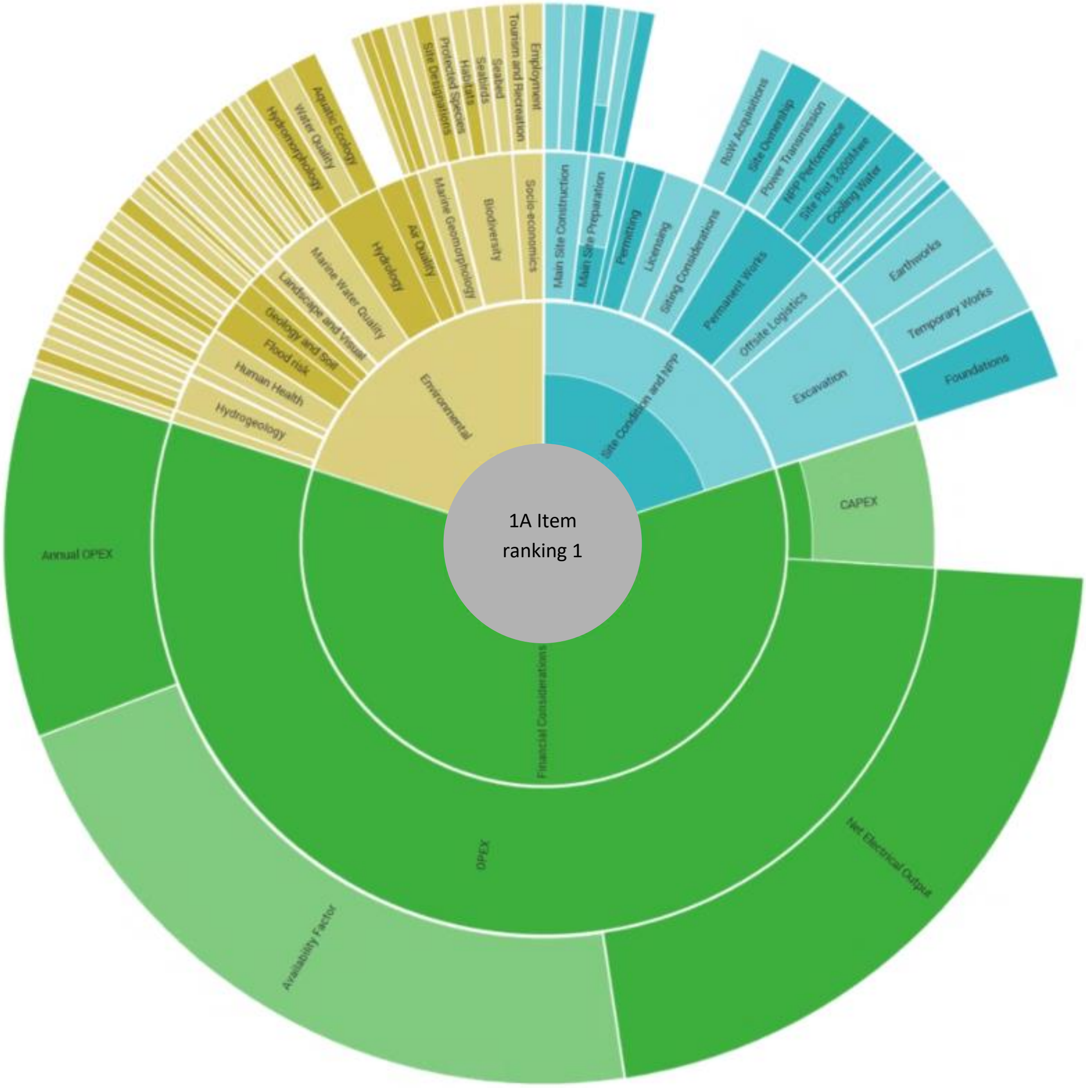
Variants and sub-variants	Technical and financial efficiency	Item ranking
Variant 1A - L-K - open cooling system using seawater	100	1
Variant 1B - L-K - closed cooling system (brackish water) using seawater	85	2
1C - L-K - closed cooling system using desalinated water	17	4
Variant 2A - ŻA - closed cooling system (brackish water) using seawater	67	3
Variant 2B - ŻA - closed cooling system using desalinated water	0	5

Source: [4]

V.2.3.8.2.1 Ranking of sub-variants

The analysis showed that in terms of technical and financial aspects, sub-variants 1A [Figure V.2- 16] and 1B [Figure V.2- 17] perform best. Sub-variant 1A ranks higher than sub-variant 1B despite higher construction requirements and an associated higher CAPEX estimate. This higher position is related to the higher net electrical output in sub-variant 1A translating into the potential for more revenue over the operational life of the NPP, which offsets the initial higher CAPEX. Sub-variant 2A [Figure V.2- 18] scores far lower than the corresponding sub-variant 1B due to higher CAPEX and OPEX related to the construction and operation of a separate pumping station, and a 10 km pipeline corridor for the make-up and cooling water channel.

Sub-variants 1C [Table V.2- 24] [Figure V.2- 19] and 2B [Figure V.2- 20] perform the worst due to the significant burden of CAPEX and OPEX on large-scale desalination plants in these sub-variants. Sub-variant 1C is superior to 2B for the same reasons as for sub-variants 1B and 2A (i.e., separate pumping station and pipeline corridor).



Partially shaded criterion - score between the highest and the lowest

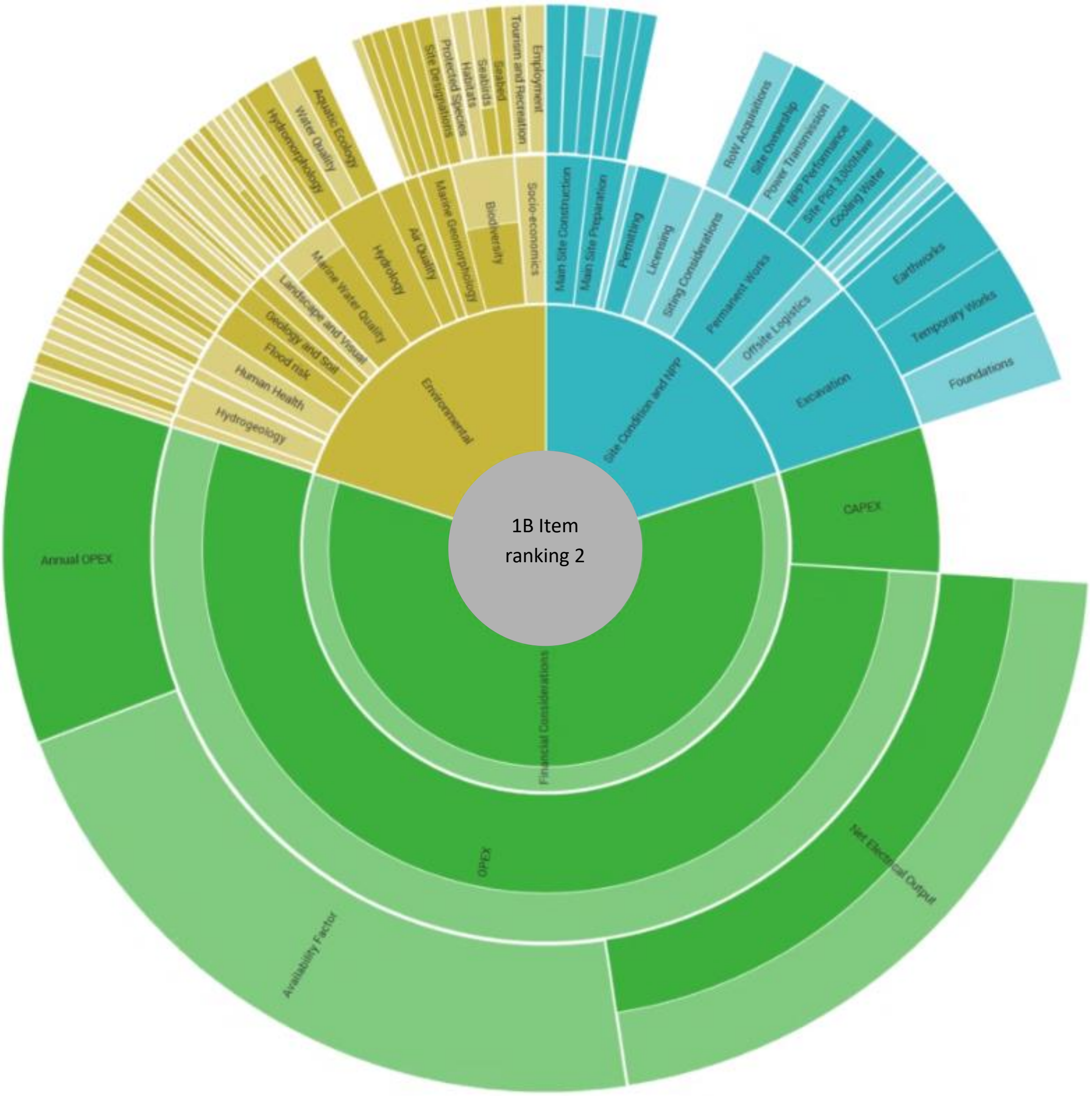
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 16 Sunburst chart of results obtained from DecisionVue - perspective Investor's preferred variant - Item 1: Sub-variant 1A

Source: [4]



Partially shaded criterion - score between the highest and the lowest

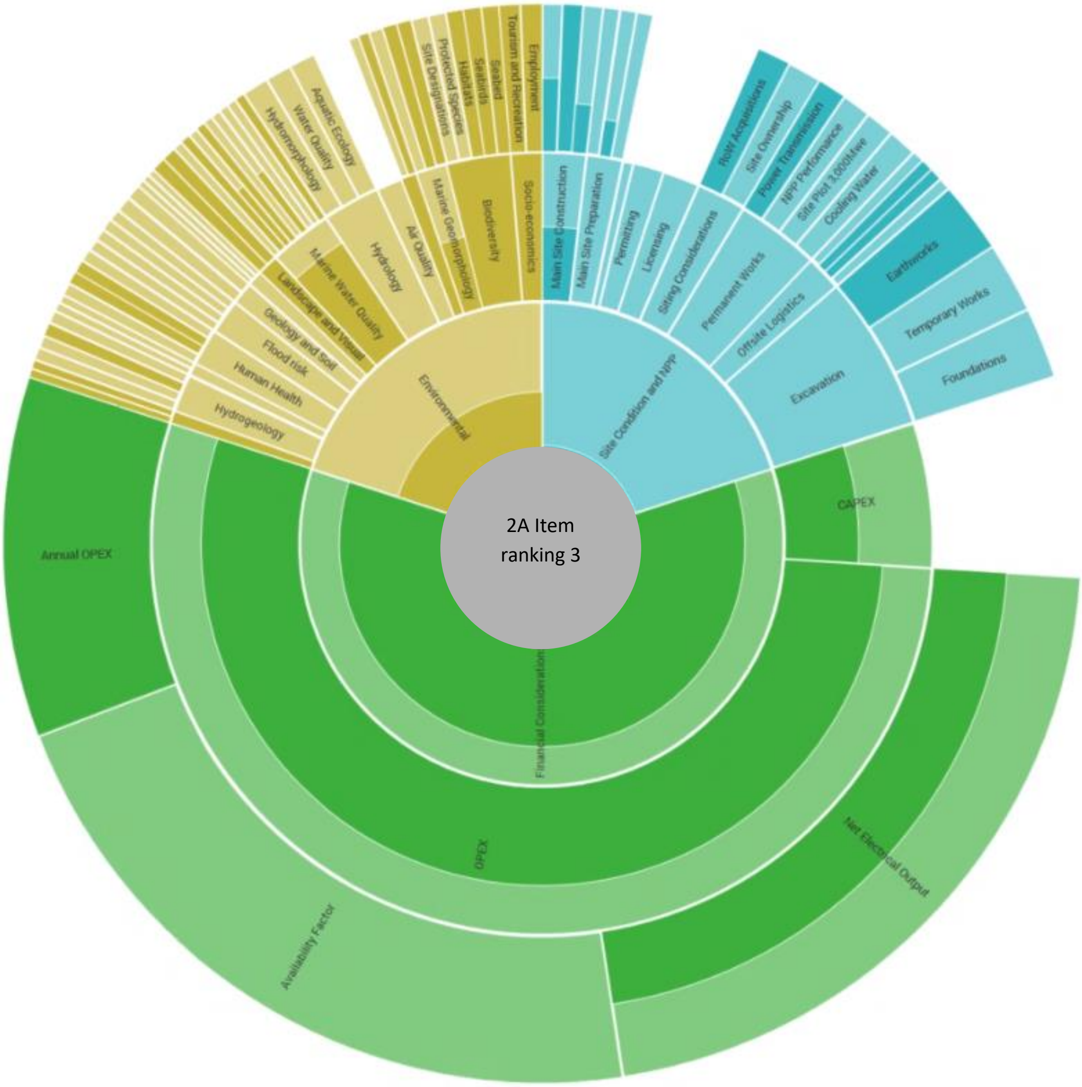
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 17 Sunburst chart of results obtained from DecisionVue - perspective Investor's preferred variant - Item 2: Sub-variant 1B

Source: [4]



Partially shaded criterion - score between the highest and the lowest

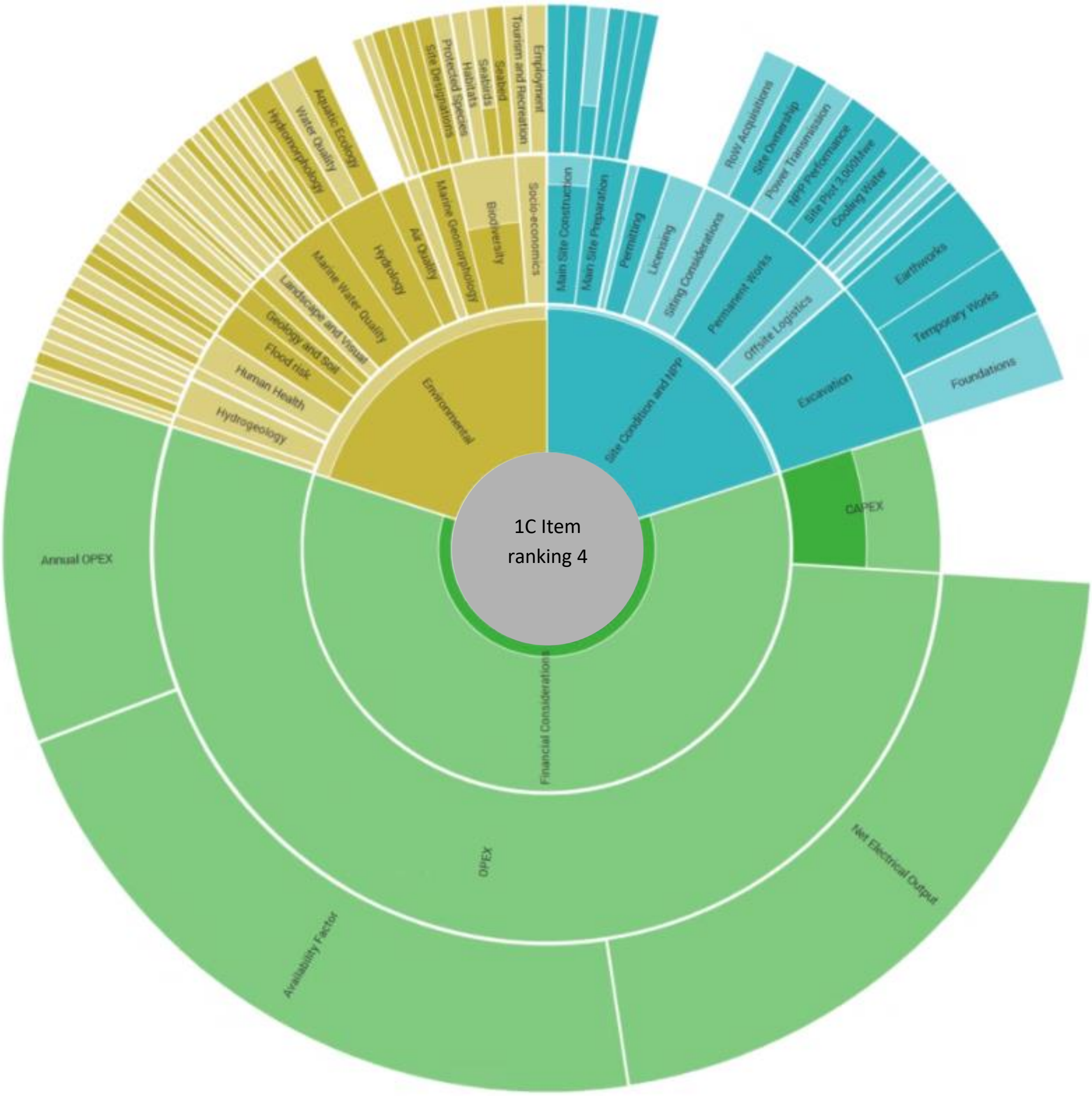
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 18 Sunburst chart of results obtained from DecisionVue - perspective Investor's preferred variant - Item 3: Sub-variant 2A

Source: [4]



Partially shaded criterion - score between the highest and the lowest

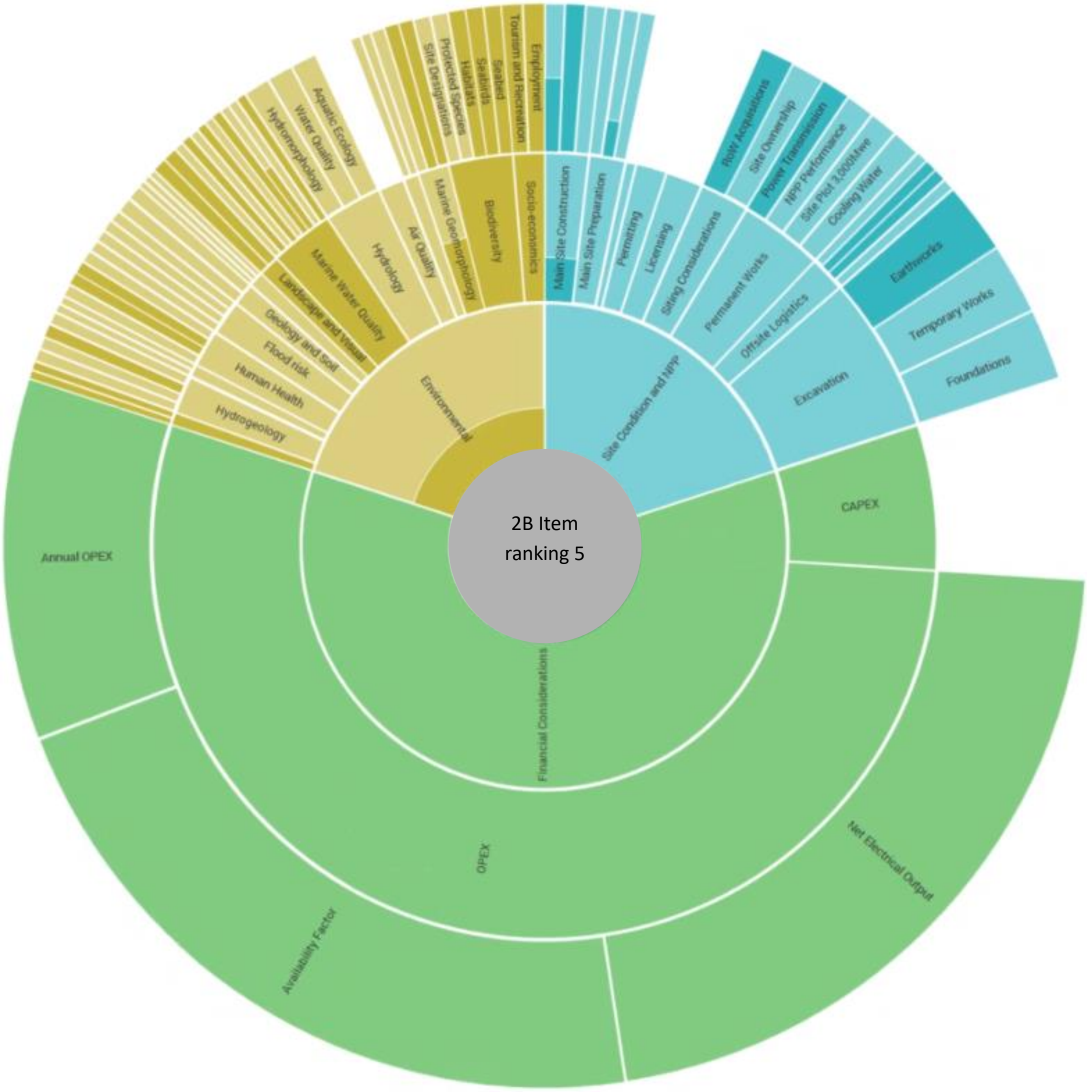
Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 19 Sunburst chart of results obtained from DecisionVue - perspective Investor's preferred variant - Item 4: Sub-variant 1C

Source: [4]



Partially shaded criterion - score between the highest and the lowest

Unshaded criterion - the lowest / total lowest score

Fully shaded criterion - the highest / total highest score

Translations of the diagram can be found in Table [Table V.2- 24]

Figure V.2- 20 Sunburst chart of results obtained from DecisionVue - perspective Investor's preferred variant - Item 5: Sub-variant 2B

Source: [4]

Table V.2- 24 Translations of terms for sunburst charts

Attribute (EN)	Kryterium główne (PL)		Criteria (EN)	Kryterium cząstkowe (PL)
Obszar tematyczny: Site condition and NPP / Aspekty związane z warunkami lokalizacyjnymi i EJ				
Main Site Construction Plot Plan	Plan działki budowlanej głównej Lokalizacji			
Main Site Preparation	Przygotowanie głównej Lokalizacji			
Excavation	Wykopy		Earthworks	Strategia realizacji robót ziemnych
			Temporary Works	Prace tymczasowe
			Foundation	fundamenty
Offsite Logistics	Logistyka poza miejscem lokalizacji			

Attribute (EN)	Kryterium główne (PL)	Criteria (EN)	Kryterium cząstkowe (PL)
Permanent Works	Stałe prace	Power Transmission Infrastructure	Infrastruktura przesyłu energii elektrycznej
		NPP Performance	Oddziaływania powodowane działaniem
		Site Plot able to facilitate 3,000Mwe	Zdolność działki do pomieszczenia infrastruktury pozwalającej na wytworzenie 3 000 MW
		Cooling Water Infrastructure	Infrastruktura wody chłodzącej
Siting Considerations	Aspekty lokalizacyjne	RoW Acquisitions	Służebność
		Site Ownership	Własność terenu
Permitting	Pozwolenia		
Licensing	Zezwolenia		
Obszar tematyczny: Financial Considerations / Aspekty finansowe			
CAPEX	CAPEX		
OPEX	OPEX	Net Electrical Output	Moc wyjściowa netto
		Availability Factor	Czynnik dostępności
		Annual Operating Expenditure	Roczne wydatki operacyjne
Obszar tematyczny: Environmental / Aspekty środowiskowe			
Socio-economics	Uwarunkowania społeczno-gospodarcze	Employment	Zatrudnienie
		Tourism and recreation	Turystyka i rekreacja
Biodiversity	Bioróżnorodność	Seabed habitats (Phytobenthos)	Siedliska dna morskiego (fitobentos)
		Sites designated for biodiversity conservation / Seabirds	Obszary wyznaczone do ochrony bioróżnorodności / ptaki morskie
		Habitats	Siedliska
		Legally protected species	Gatunki prawnie chronione
		Sites designated for biodiversity conservation: Baltic Coastal Waters SPA	Obszary wyznaczone do ochrony bioróżnorodności OSO Przybrzeżne Wody Bałtyku
Marine and coastal geomorphology	Geomorfologia morza i wybrzeża	Coastline processes (accretion / erosion)	Procesy przybrzeżne (akrecja/erozja)
		Seabed features	Elementy dna morskiego
		Dune system	System wydm
Climate and carbon	Klimat i emisja dwutlenku węgla	Carbon emissions	Emisje dwutlenku węgla
		Climate Change Resilience	Odporność na zmianę klimatu
Air quality	Jakość powietrza		
Hydrology	Hydrologia	Aquatic ecology	Ekologia wód
		Water quality	Jakość wody
		Hydromorphology	Hydromorfologia
Marine Water quality	Jakość wody morskiej	Turbidity levels	Zmiany w poziomach zmętnienia
		Bathing Waters	Wody w kąpieliskach
		Eutrophication	Eutrofizacja
		Cooling chemicals	Poziomy substancji chemicznych w systemie wody chłodzącej
		NPP process chemicals	Poziomy substancji chemicznych z procesów EJ
		Species impingement	Przechwytywanie żywych organizmów
		Increased salinity	Podwyższone zasolenie
		Heat emissions to water	Emisja ciepła do wody
		WFD / MSFD	RDM/RDSM
Landscape and visual	Krajobraz i walory wizualne	Landscape effects	Walory krajobrazowe
		Visual effects	Walory wizualne
Noise and vibration	Hałas i wibracje	Road traffic	Ruch drogowy
		NPP operation	Eksploatacja EJ

Attribute (EN)	Kryterium główne (PL)	Criteria (EN)	Kryterium cząstkowe (PL)
		Rail traffic	Ruch kolejowy
Geology and Soil	Geologia i gleby	Soil degradation	Degradacja zasobów glebowych
		Environmental risk	Ryzyko dla środowiska
Flood risk	Ryzyko powodziowe	Ground water flooding	Powódź od wód gruntowych
		Surface water flooding	Powódź od wód powierzchniowych
		Fluvial flooding	Powódź rzeczna
		Marine flooding	Powódź od strony morza
Human health	Zdrowie ludzkie	Increased community health	Wzmożone zagrożenie zdrowia
		Emergency services	Służby ratunkowe
		Waiting times	Czas oczekiwania
		Population	Ludność
Historic Environment	Otoczenie historyczne	Architectural Number	Liczba zabytków architektury
		Architectual value	Wartość architektury
Hydrogeology (Groundwater)	Hydrologia (wody gruntowe)	Abstractions	Pobory wody
		Conditions supporting GWDTEs	Warunki wspierające GWDTE
		Watercourses and WFD surface water bodies	Cieki wodne i JCWP w rozumieniu RDW
		Aquifers and WFD groundwater bodies	Warstwy wodonośne i JCWPd w rozumieniu RDW
Electromagnetic Field Levels and Ionising Radiation	Poziomy pola elektromagnetycznego i promieniowanie jonizujące	Electromagnetic Fields	Pola elektromagnetyczne
		Ionising Radiation	Promieniowanie jonizujące

Source: [4]

V.2.3.8.2.2 Sensitivity analysis

Costs were based on publicly available data, but in each case only one project was used as an example, so they required additional scaling before being applied to the Project.

The overall weighting of CAPEX to OPEX under the financial criteria is such that the scoring results are not highly sensitive, and the factors affecting the net electrical output of the NPP are much more significant. This supports the conclusion that even with a higher estimated CAPEX for sub-variant 1A, this sub-variant performs better than all other sub-variants.

There are two criteria that directly affect the NPP net electrical output, one of which is the electrical demand of the supporting infrastructure (e.g., cooling towers and desalination plants), and the other is the availability of the nuclear power plant (the part of the year during which the NPP generates electricity).

Based on these criteria, it can be seen that reducing the estimated CAPEX for sub-variant 1A (e.g. reducing the length of the intake and outfall tunnels) will enhance the financial performance of this sub-variant compared to all other sub-variants, provided that this does not lead to a reduction in nuclear plant availability.

V.2.4 Indication of the variant proposed by the Investor, environmentally preferable rational variant, and rational alternative variant

After comparative and multi-criteria analyses, it turned out that sub-variants 1A and 1B ranked the highest. The analyses showed that sub-variants 2A, 1C and 2B are feasible, but based on the criteria used in these analyses their performance was inferior to sub-variants 1A and 1B. Sub-variant 1B was ranked the highest when considering environmental criteria only, and sub-variant 1A came in the second place. On the other hand, when environmental and financial aspects are taken into account simultaneously, it turns out that the best sub-variant is 1A, with sub-variant 1B classified on the second place.

Sub-variant 1B received the highest score for environmental aspects, but the sensitivity analysis showed that technical sub-variant 1A performs best with respect to a number of core criteria for environmental aspects that received relatively low weights based on the expert panel's opinions. However, these criteria are linked to some of the most obvious Project environmental impacts (e.g. impacts on the landscape, traffic during the construction stage and impacts on the acoustic environment). As a result, if the public considered the criteria that received relatively low weights to be more important, sub-variant 1A would be more favorable than sub-variant 1B.

The sensitivity analysis also showed that the ratings of the sub-variants with respect to financial aspects are highly dependent on the core criteria of Net Electrical Output and NPP Capacity Factor, and a reduction in the weights of any of these criteria would result in a reduction in the difference in scores between sub-variant 1A and the other sub-variants.

The results of the analyses clearly point to the fact that an open or closed cooling variant using sea water works far more effectively than the closed cooling system using desalinated sea water, irrespective of the site of the Project. This combines significantly with the energy absorption of large desalination plants, which reduces the net electrical output and increases operating expenses. Other environmental factors also contribute to the low efficiency of the closed cooling system using desalinated sea water. The siting of the Project affects the final scoring of the individual sub-variants, albeit to a lesser degree than the technological solutions of the cooling water systems.

Based on the results of the comparative and multi-criteria analysis, it can be concluded that:

- **the variant proposed by the Investor for execution is sub-variant 1A. This is the sub-variant that received the highest scores while considering environmental aspects along with the other criteria;**
- **the rational and environmentally preferable variant is sub-variant 1B. The scores for this sub-variant were equal to or higher than for sub-variant 1A. However, the difference between sub-variants 1B and 1A is small and both sub-variants have comparable environmental impacts;**
- **the rational alternative variant is sub-variant 1B. This variant was selected due to its lower environmental impact - based on the results of the multi-criteria analysis - than the other sub-variants, i.e. 1C, 2A and 2B.**

V.3 Description of anticipated mitigation activities (avoidance, prevention, reduction or offsetting)

This chapter presents mitigation activities/measures for environmental components affected by the planned Project, the application of which will make it possible to prevent or reduce significant negative impacts on the environment in connection with the implementation of the planned Project. A detailed description of the mitigation measures is provided in Volume IV for each impact. However, not all components of the environment described in the EIA Report require the use of such measures, or it was not possible or reasonable for all of them to be designed at the current, early stage of the project. Therefore, the description of the mitigation measures will be clarified at the stage of the reassessment of the environmental impact of the planned Project. In addition, the performance of a post-project analysis for the Project is recommended. At the same time, an analysis was also carried out to determine whether the impact of the Project on the biotic environment and ambient air quality require offsetting.

Mitigation measures are described for the preferred Project variant, namely Variant 1 – Lubiatowo - Kopalino site, Sub-variant 1A with an open cooling system using sea water. For several environmental components, an additional division of mitigation measures into land and marine area was made. In other cases, the division was not required because whether a land or marine area is involved is clear from where the component concerned is situated.

In order to reduce the environmental impact of the Project, development and construction works should be carried out under nature conservation supervision. In addition, individual mitigation activities should be agreed with nature conservation supervision authorities. A nature conservation supervision authority should be established before the start of the development works and before drawing up a plan for protective measures and monitoring of individual environmental components for the construction phase of the Project. Both the plan for protective measures and monitoring of individual environmental components and annual reports on the implementation of activities in this area should be submitted to the Regional Director for Environmental Protection for information purposes.

Mitigation measures for most environmental components are presented for the construction and operational phases of the Project. The nuclear power plant decommissioning will be subject to a separate environmental impact assessment procedure and will be covered by a separate decision on environmental conditions. Therefore, no mitigation measures for the decommissioning phase have been proposed.

The accompanying infrastructure will be an important source of environmental impact, but mitigating these impacts does not fall within the scope of the environmental impact assessment for the Project, and therefore it is not described in this chapter. Mitigation methods for the associated infrastructure should be taken into account when preparing separate EIA Reports and design documentation for these projects. Depending on the environmental component concerned, some chapters of Volume IV concerning individual impacts and the chapter on cumulative impact [Chapter IV.19], indicate the possibilities of mitigating the impact from the associated infrastructure. However, they should be treated as a guide for analysis and laid out in more detail in the EIA Report for the associated project concerned.

V.3.1. Mitigation activities

V.3.1.1 Natural environment

With regard to the natural environment, the components of the natural environment considered included macroscopic fungi, lichenised fungi, bryophytes, vascular plants, natural habitats, terrestrial and freshwater invertebrates, ichthyofauna, herpetofauna, i.e. amphibians and reptiles, avifauna, chiropterofauna and other species of mammals for which the risk of significant impacts related to the implementation of the Project was identified. They are divided into the following categories:

- species for which there is no need for mitigation activities,
- species to which mitigation activities cannot be applied,
- species for which mitigation activities are possible and justified,

and the list of guidelines was developed for the third of the above-mentioned categories, i.e. species for which mitigation activities were found to possible and justified.

The basis for subsuming the discussed components of the natural environment in one of the above categories included:

- the range of occurrence at the national and regional level, frequency of occurrence and territorial coverage,
- degree of hazard and protection categories (species subject to strict and partial protection).

Measures mitigating negative environmental impacts were developed for each phase and stage of the Project (taking into account the reservation made in the introduction to this chapter).

V.3.1.1.1 Construction phase

Most of the minimising measures proposed in this chapter concern the construction phase, but some can also be continued in the operational phase of the Project, e.g. lighting suitable for bats both at the construction site and in the later period, when the NPP is operational.

LAND AREA

Macroscopic fungi (*Macromycetes*)

- Metaplantation (transfer of all or part of the population from an exposed site to another, suitable in terms of habitat), but limited to a small number of species, e.g. taxa, e.g. from the *Geastrum* genus.
- Activities leading to the creation of ecological niches that will allow spontaneous colonisation, e.g. by saproxylophagous fungi – the average amount of dead wood in Polish forests is about 6 m^3/ha, so as a mitigation measure, it is proposed to leave at places selected for this purpose some of the harvested wood and post-logging residues with a diameter of less than 5 cm. The quantities and sites should be agreed with the owner or manager of the land.

Lichenised fungi (lichens)

- All taxa were classified into the category of species for which there is no possibility of applying mitigation measures, since it is a group of organisms which are very complex in ecological and biological terms, most of them being highly sensitive to changes in environmental conditions. The only recommendation is to monitor the patches that will be preserved in selected areas which are not subject to direct interference in the construction phase.

Bryophytes

- For this group, no possibility of effective mitigation measures have been identified at the present stage of the project, except for the monitoring of patches selected at the reassessment stage, which will be preserved in areas which are not subject to direct interference in the construction phase.

Vascular plants

- The metaplantation of the species specified in Volume IV of the EIA Report seems to be the only effective solution. The extent and site of metaplantation should be agreed with nature conservation supervision authorities at the development design stage.

Natural habitats

- In most cases, it will be impossible to undertake effective mitigation activities for most of the identified natural habitats, which involves many unrecoverable factors, such as topographic, climatic, ecological and other conditions. In Variant 1 – Lubiatowo - Kopalino site, however, it was found that in the case of patches of habitat in a favourable (FV) conservation status of Habitat 2180 – Wooded dunes of the Atlantic, Continental and Boreal region, it is possible to restore them as part of minimisation actions, and this action will be combined with the metaplantation of the *Empetrum nigrum* black crowberry. Similarly, in the case of Habitat 2170 – Dunes with *Salix repens ssp. argentea* (*Salicion arenariae*), restoration of habitat patches in combination with the metaplantation of sand willow (*Salix arenaria*).

Freshwater invertebrates

- For this group, no need for mitigation activities was found, with only the monitoring of the water level needed at land sites (mid-forest reservoirs located within a radius of 500 m from the boundaries of the Project Area and monitoring of the groundwater level on piezometers located within this area).

Terrestrial invertebrates

- In the context of three species of ants threatened by the implementation of the Project, the identified nests are planned to be transferred to other convenient habitat locations in the coastal belt. For the European red wood ant *Formica polyctena*, methods such as anthill transfer are well described in scientific sources and can be applied with a high probability of success. The same is true of the black-backed meadow ant *Formica pratensis* and the red wood ant *Formica rufa*, with there being an opportunity to transfer the identified anthills before proceeding with development work. Due to the fact that the potential identified anthills may cease to exist or new colonies may appear, a new inventory of anthills will be carried out before starting development works on the planned construction site and in its immediate vicinity. Those ant colonies that will be suitable for transfer will be transported to a convenient habitat location at a short distance but outside the direct impact zone of the Project.
- *Mythimna litoralis* is a moth found only in dune habitats, and its larvae feed on plants from the *Poaceae* family, of which there is one species in Poland, i.e. the European beachgrass *Ammophila arenaria*. The species is rare, and in order to minimise the impact on this species, an inventory should be made before commencing work on dune habitats, including the search for larvae on host plants and, if found, the larvae should be moved to another convenient habitat containing the European beachgrass, making sure that the new locations, i.e. to places that are subject to as little human pressure as possible, e.g. with restrictions on the free movement of people.
- *Stenagostus rufus* is a beetle of the *Elateroidea* family, considered a rarity in Poland. In northern Poland, it is known only from individual sites on the island of Wolin and on the Baltic coast. This species is associated with dead wood, and the larvae of this beetle feed on xylophagous species such as *Arhopalus rusticus*, *Spondylis buprestoides* and *Stictoleptura rubra*. As a proposed mitigation activity for this species, an inventory of potential habitats, dead pine stumps, will be made before proceeding with development work. If larvae of the species are found, attempts will be made to transfer the stump along with the soil layer to another convenient habitat outside the area of the planned Project. An additional action coinciding with the activities proposed in relation to mycoflora and herpetofauna will be to leave outside the planned Project Area sites with dead pine wood, which will come from the felling of trees and shrubs for the Project, in order to create potential habitats for this species.
- The sand hopper *Talitrus saltator* is a species of invertebrate whose habitat is on beaches (in the spring/summer/autumn activity season, the beach boundary is flooded with water, while in winter the species moves to the higher parts of the beach towards the dunes). Due to the discontinuous nature of its occurrence and the fact that the species can actively move on the beach, and taking into account, its conservation status, mitigation activities for this species should be taken into account. Works planned on

or along beaches should be limited as far as possible to a period outside the main activity of the species (summer), and should be preceded by a detailed inspection before the commencement of works. If high densities of the species are found, e.g. above (150–200 individuals per square metre), as many sand hoppers as possible should be transferred to another part of the beach. The species actively moves at night and reacts to artificial light by showing positive phototaxis, which additionally allows individuals to be collected and transferred to other convenient and safe locations outside the area of works. The industry literature mentions several methods for trapping the species, e.g. pitfall traps and methods of active species search (night, with the use of light). The appropriate method will be selected when designing mitigation activities at the reassessment stage.

Ichthyofauna (fish)

- There are no watercourses in the Project Area, but it borders on the Kanał Biebrowski, which is a regulated watercourse subject to maintenance. Nevertheless, species such as the *Perca fluviatilis* common perch, the *Salmo trutta m. fario* river trout and the *Lampetra fluviatilis* river lamprey, i.e. a species subject to partial protection listed in Annex II to Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive) [27] were found during the inventory (in site 27, in the vicinity of the Project Area), the latter also appearing on the red list of endangered and threatened animals in Poland. The river lamprey was found only once during the inspection, which took place in the spring period, and it is for this reason that the proposed mitigation activity will be to ensure unobstructed flow in the Kanał Biebrowski. Despite its anthropogenic form, this watercourse may be a potential migration route for anadromous species such as: salmonid fish (sea trout, salmon) and lampreys (river lamprey, sea lamprey).

Herpetofauna (amphibians)

In the context of the discussed group, the Project Area is not an area with habitats that are most suitable for habitation. Most of the area consists of relatively dry habitats within the coastal pine forest and large areas with marsh briar. In a large part of this area, there are no sufficiently humid places, generally preferred by amphibians. Potentially convenient sites include inter-dune depressions and terrain depressions in which peatland patches can be found. Along the southern part of the Project Area, there is also the Kanał Biebrowski.

- The *Lissotriton vulgaris* common newt was found in one water reservoir (site 600). This reservoir was probably formed in the place of the former network of drainage ditches. During the survey, the reservoir was heavily overgrown (with approximately 30% of the water surface exposed) with a growing peat mat. As part of the mitigation activities, animals are to be transferred (from site 600) to another convenient habitat location outside of the area impacted by the Project. In addition, the performance of a detailed inventory survey is recommended in the Project Area before the start of the development stage in order to verify possible new sites for the common newt. Such surveys should in particular take into account the southern part of the area where the existing network of drainage ditches and terrain may provide favourable habitats for the species. The surveys should also cover the sites of depressions within habitats 2180 and 7140, where the presence of protected amphibians, including the common newt, can also be expected.
- The crested newt *Triturus cristatus* found on three sites a short distance from the Project Area (Site 582 located about 1 km from the Project Area – Lake Kopalińskie in a shallow bay overgrown with alder carr; site 593, a mid-forest pond situated approximately 100 meters to the south of the Project Area, with an area of about 0.2 ha and a depth of over 1 m, with approximately 60% of the water surface covered with vegetation; site 675 situated about 500 m from the Project Area, i.e. a water reservoir probably of natural origin, with an area of approximately 0.5 ha and a depth of over 1 m, with about 50% of the water surface overgrown with vegetation). Due to the fact that crested newts can migrate by land (over distances from approximately 400 to 1,200 metres), it should be covered by the survey programme at the pre-development stage, and if the species is found within the boundaries of the Project Area, all specimen

should be moved to a predetermined site (natural or artificially created pond or complex of ponds). At the current stage of the project, no interference with the populations inhabiting the aforementioned sites numbered 582, 593, and 675 is planned.

- The common frog *Rana temporaria*, i.e. a species that has been found on 2 sites in the Project Area. One of the sites (site 600) is the same as that described above for the common newt. The second site (No. 598) is a shallow drainage ditch fed by a spring, periodically drying out. As a mitigation activity for the common frog, as in the case of the common newt, the animals are intended to be trapped and transferred from identified sites to other convenient habitats located outside the area impacted by the Project. In addition, due to the movement of amphibians, an inventory of amphibians should be made before proceeding to the development stage. As in the case of newts, the surveys should primarily cover depressions within habitats 2180 and 7140, where the presence of amphibian species can also be expected, and if new sites are found, the animals should be moved to other convenient habitats outside of the area impacted by the Project.

Herpetofauna (reptiles)

In the Project Area, three species of reptiles were found (the viviparous lizard *Zootoca vivipara*, the common European adder *Vipera berus* and the slow worm *Anguis fragilis*), and despite significant efforts, a species potentially present in the location, i.e. the smooth snake *Coronella austriatica*, was not found, while it was observed in 2010 in the vicinity of Białogóra (about 8 km east of the Project Area). This snake is a rare species with a relatively low population, but it is found practically throughout the country.

The viviparous lizard was found at four sites in various parts of the aforementioned survey area, including its northern part near the location where Habitat 2180 merges into dunes, but also in the south near the Kanał Biebrowski, the viviparous lizard was found at one site located in the southern part of the Project Area, in the Kanał Biebrowski area, and the slow worm was observed at four sites mainly in the west-southern part of the area, all found near drainage ditches or the Kanał Biebrowski.

- In order to minimise impacts, before proceeding the commencement of the development stage, animals should be caught, preferably in the period before autumn migration, and moved outside the future area of works. Before the commencement of construction works, the area should be protected against the entry of animals, e.g. by using guidance bands, especially in transport routes (e.g. along service roads) and anthropogenic traps, which will be regularly inspected by trained personnel supervised by experts in the field of herpetology. The location of the bands and traps should be determined by a qualified herpetologist. As part of additional activities, piles of branches/dead wood (harvested during felling operations) are proposed to be set up outside the area of works, at convenient locations (coastal strip areas), which will provide shelter to herpetofauna (the same action will be taken for macrofungi, where dead branches may form additional sites to be inhabited by mycoflora). Such places provide daily shelters as well as winter hibernacula and will have a positive effect on the maintenance of the local population, and their location should be determined by a herpetologist.

Avifauna (birds)

- One of the recommended mitigation activities in the context of breeding avifauna will be the works related to the preparation of the site (tree felling, rootstock removal and site levelling) outside the bird breeding season or after performing a site visit and obtaining the consent of the nature conservation supervision body.
- Works, especially those concerning the felling of trees and the removal of vegetation and shrubs, are recommended to be carried out under the supervision of an ornithologist.
- Before proceeding to the development stage, a site visit should be carried out by a qualified team of ornithologists to verify that there are no nesting birds in the immediate area of works.

- As an additional mitigation activity related to the felling of part of old trees, including hollow trees, birdhouses are planned to be hanged in forests in areas outside the Project Area.

Chiropterofauna (bats)

A bat survey in the Project Area, based on ultrasonic detection of bat activity, identified six species of bats commonly found in Poland. These were all three species of *Pipistrellini* regularly found in Poland: the soprano pipistrelle *Pipistrellus pygmaeus*, the common pipistrelle *Pipistrellus* and Nathusius' pipistrelle *Pipistrellus nathusii*. The serotine bat *Eptesicus serotinus* was also found in a significant proportion. Other species were much less common.

- As a mitigation activity for bats in the context of the coastal migration corridor in the course of implementation of the Project, tree clearance is to be carried out to the necessary extent based on a tree clearing plan agreed with bat experts and preservation, as far as possible, of a tree belt within the technical coastal strip, so as to maintain its continuity.
- Immediately after the completion of the construction works, it is necessary to restore the tree stock at least partially within the coastal strip that constitutes a migration corridor for bats.
- Another mitigation activity is to avoid the unjustified use of green and red lights unless it is necessary for technical reasons. The recommendation does not address the requirement to ensure safety in accordance with legal requirements, e.g. some high structures must be illuminated with red light (obstruction lighting) in compliance with legal requirements.
- As early as the development stage and in the subsequent stages and phases of the Project, it is proposed to limit unnecessary night lighting to places where work is in progress and to transport routes, as well as places that require lighting for safety reasons.
- Another good practice is the use of motion sensors in places less frequented by employees (such action can also be used in the operational phase), or the planning of works that require extensive lighting (e.g. round-the-clock work carried out due to the technological requirements of construction or production) in periods when animals are less active, e.g. autumn and winter.
- It is also recommended to limit the use of sodium lighting and wide-band or UV lighting, and if possible to replace this type of light sources with another, e.g. low-pressure sodium lamps or fully-directional narrow-band LED lamps. The use of shielded directional lamps leads to a significant reduction in light emissions. It will also be important to determine the direction of lighting, as lights shining towards the sea should be limited, in order to leave the coastal strip unlit so as to avoid disturbing the ecological corridor. This measure will also be beneficial for other species, including invertebrates, e.g. sand hoppers show positive phototaxis, and this could cause disturbances in their life cycle. Many other species of invertebrates are attracted to light, which additionally attracts bats, which often feed near lamps (e.g. common, soprano and Nathutius' pipistrelles, or the serotine bat). However, this does not apply to all species of bats, e.g. mouse-eared bats (the *Myotis* genus) avoid heavily lit zones, which means that they lose the ability to feed in many areas. The mitigation activites in this case will also be the preference for the use of light sources that do not emit UV radiation.

Mammals

Mitigation activities in the case of mammals will apply to three species due to the fact that these are mobile species that often have significant home ranges, i.e. the wolf *Canis lupus*, the otter *Lutra*, the European beaver *Castor fiber*. The results of the inventory showed that wolves mainly use the coastal strip of the forest, primarily in the period from autumn to spring, but also traverse the areas located south of the Project Area (the Kanał Biebrowski) and north of the site (beach). As regards mitigation activities for the wolf population, their success will be conditional on taking into account the specificities of the associated infrastructure, in particular the linear infrastructure. Related mitigation activities should be taken along the routes of the associated road and rail infrastructure.

MARINE AREA

Control of marine works and associated pollution

All vessels associated with the Project would be required to adhere to international best practice, including that outlined within the International Convention for the Prevention of Pollution from Ships (MARPOL) such as the 15 ppm oil limit for water in operational vessel discharges.

In order to reduce the risk of invasive non-native species (INNS) being introduced with ballast water, all vessels (including dredgers and supply ships delivering abnormal loads to the MOLF) must therefore carry:

- A ballast water management plan specific to each ship, including a detailed description of the actions to be taken to implement the ballast water management requirements and supplemental ballast water management practices;
- A ballast water record book to record when ballast water is taken on board, circulated or treated for ballast water management purposes and discharged into the sea. It should also record when ballast water is discharged to a reception facility and accidental or other exceptional discharges of ballast water;
- An International Ballast Water Management Certificate (for ships of 400 gt and above) to certify that the ship carries out ballast water management in accordance with the BWM Convention and specifies which standard the ship is complying with, as well as the date of expiry of the Certificate.

Land based sources of marine pollution

At the development stage, a system of drains and open ditches will be provided in the coastal strip to ensure water removal from paved and converted areas [Chapter II.3 and Chapter IV.8.3] together with the construction of decanters, separators and retention basins, the use of which will make it possible to address issues related to compliance with surface water quality standards for the discharge of wastewater and drainage of rainwater carried by wastewater and drainage systems.

It is recommended that the following best practice measures be incorporated into the construction site drainage system:

- Ensuring that the undisturbed topsoil layer is maintained as long as possible in the areas planned for conversion;
- Providing a network of drains and drainage ditches for hardstanding/converted areas;
- In the case of stockpiles of loose material or topsoil, consideration should be given to covering them with appropriate deep-rooted plant species, which will reduce erosion and increase retention;
- Connecting drainage networks and wastewater system to the components for the pre-treatment of rainwater and water from the drainage of deep excavations: sedimentation tanks, separators, retention basins;
- Maintaining drainage/wastewater components in good state of repair so as to ensure that environmental quality standards are complied with in line with applicable laws and regulations.

Pollution risk from fuels, lubricants, chemicals and high-alkaline seepage from the cement bonding process would generally be controlled across the whole site by good operational and maintenance practice, including:

- Storage of fuel and oil in leak-proof tanks;
- Storage of cement powder in secure dry indoor areas or silos;
- Provision of oil interceptors on drainage lines from hardstanding areas where refuelling and maintenance are to take place;

- Minimisation of the operation of the facility in water, and the use of biodegradable lubricants and hydraulic oils where this cannot be avoided;
- Monitoring pour volumes, especially of grout, to minimise losses into groundwater;
- Returning waste concrete to the batching plant for re-processing and re-use of aggregate;
- Ensuring that remaining binder materials (cement) and hardened concrete are disposed to licensed disposal sites;
- Establishing and implementing protocols to respond to any pollution incident or potential incident, including recording of near misses.

The mitigation measures specified above are assumed to be implemented as part of procedures subject to periodic reviews. Discharges from construction site drainage systems, either to inland or to coastal waters, would be subject to securing the relevant water permits.

Underwater noise (piling)

The UK's "Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise" outlines a protocol for the mitigation of potential waterborne noise impacts arising from pile driving during offshore wind farm construction. The protocol was developed to reduce to negligible levels the potential risk of injury or death to marine mammals in close proximity to piling operations. This protocol may also be useful to other industries in the marine environment, which use pile driving [125]. The protocol provides guidance on mitigation techniques to be implemented before commencement of (Section 1) or during piling operations (Section 2). The recommended mitigation techniques are summarised below. These measures are industry standard and are also detailed in [Chapter IV.10.2].

<u>Mitigation activities to be implemented prior to the commencement of piling:</u>

- Demonstration that Best Available Techniques (BAT) are being used. Techniques such as hammer modifications, sleeving or muffling, the use of vibratory hammers and gravity-based piling may all reduce noise levels;
- Seeking to provide appropriately trained and equipped Marine Mammal Observers (MMOs). The primary role of the observers should be to detect marine mammals and to potentially recommend a delay in the commencement of piling activity if any marine mammals are detected;
- Establishing communication procedures between the MMOs and piling crews, including a formal chain of communication between the observers and the person who can stop the piling operation;
- Establishing a mitigation zone. This is an area in which the MMO operatives will monitor either visually and/or acoustically for marine mammals before piling commences. The extent of this zone should be considered during the environmental impact assessment and be agreed with the environmental supervision body. The radius of the mitigation zone should be no less than 500 metres, measured from the pile location;
- Make use of acoustic deterrent devices (ADDs) and/or pingers to deter marine mammals and fish from the mitigation zone and waters immediately adjacent to the works, and especially if they are persistently present and the commencement of piling is being significantly delayed. The use of ADDs and/or pingers would only be permitted, when an associated European Protected Species (EPS) disturbance licence has been provided. The use of ADDs and/or pingers would only be permitted when a relevant European Protected Species (EPS) disturbance licence has been provided.

Mitigation activities to be implemented during piling operations

- Piling at night or in poor visibility conditions: piling should not be commenced during periods of darkness or poor visibility (such as fog), or during periods when the sea state is not conducive to visual mitigation (above Sea State 4), as there is a greater risk of failing to detect the presence of marine mammals;
- Pre-piling search: the mitigation zone should be monitored visually by MMOs for an agreed period prior to the commencement of piling. It is recommended that the pre-piling search duration should be a minimum of 30 minutes;
- Delay if marine mammals are detected: piling should not be commenced if marine mammals are detected within the mitigation zone or until 20 minutes after the last visual or acoustic detection;
- Soft-start: the soft-start is the gradual ramping up of piling power, incrementally over a set time period, until full operational power is achieved. The soft-start duration should be a period of not less than 20 minutes. When piling at full power, there is no requirement to cease piling or reduce the power if a marine mammal is detected in the mitigation zone (it is deemed to have entered "voluntarily"). It is also acknowledged that, for engineering reasons, it may not be possible to stop piling at full power until the pile is in final position;
- Pause in piling operations: if there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences. However, if a watch has been kept during the piling operation, the MMO operative should be able to confirm the presence or absence of marine mammals, and it may be possible to commence the soft-start immediately;
- Acoustic Deterrent Devices (ADDs): The use of devices that have the potential to exclude animals from the piling area should be considered. ADDs should only be used in conjunction with visual and / or acoustic monitoring;
- Any fish kills will be recorded (species and number) and operations and procedures will be periodically reviewed and/or adjusted to avoid/minimise future fish kills.

Light pollution

Lighting will be arranged so that glare and light spill into the marine environment is minimised. This measure will apply to land-based lighting as well as lighting on vessels operating in the adjacent coastal environment. A lighting strategy will be prepared prior to commencement of works to outline the measures to be taken to minimise any light spill into the marine environment.

V.3.1.1.2 Operational phase

LAND AREA

Ichthyofauna (fish)

- Ensuring unobstructed flow in the Kanał Biebrowski.

Chiropterofauna (bats)

- Detailed requirements for the minimisation of impacts in the context of the use of artificial lighting are described for the construction stage.

MARINE AREA

Minimisation of the impact on fish

Fish Recovery and Return System (FRRS)

Measures have been incorporated into the initial design of the cooling water system to minimise impacts on marine ecology. Based on an understanding of the local marine ecological communities, consideration has been given to the most appropriate location of the intake and outfall headworks, as well as the radial design and dimensions of the intake heads/jets to achieve target water velocities below 0.3m/s for Sub-variant 1A – open cooling system. This would help to reduce the degree to which organisms are impinged (captured in the flow of the cooling water intake) or entrained (pass through the cooling water circuit).

The FRRS is the best available technology in the United Kingdom [118], [126] and would be designed to enable fish entrained within the cooling water system to be recovered on travelling screens and conveyed back to sea water via a dedicated fish return channel. HELCOM [52] provides general requirements concerning BAT. The European BAT reference note on industrial cooling [156], although not strictly applicable to the Project, nonetheless also provides useful information for defining BAT. The FRRS can also benefit invertebrates such as crustaceans and molluscs that have been entrained into the cooling water system.

Best practice requires the following design and operational features to be met [135], [134]:

- A fish recovery and return system and a fish return channel/pipeline should be provided;
- Biocides should only be applied to the return channel/pipeline where it can be shown that the toxic risk is negligible to avoid toxic exposures;
- A continuous wash-water supply should be provided to ensure sufficient depth to keep fish immersed and moving along the return channel/pipeline.
- Fish return gullies should be smooth, with any joints properly grouted and finished;
- Return gullies should have a minimum of 0.3 m diameter with at least 0.5 m diameter or larger for the main return channel run;
- Swept bends of radius greater than 3 m should be used;
- Any changes in slope of launders should use a minimum 3 m swept bend radius to avoid flow separation from the launder bed; The fall on launder sections upstream of horizontal bends should be restricted to a maximum of 1:50;
- Fish return lines should be covered to prevent bird predation and algal growth, with access for cleaning;
- Where the fish return launders or channels/pipelines are not sufficiently elevated, additional flow rate can be provided using fish-friendly pumps;
- The channel/pipeline should not be longer than necessary, to reduce the time of fish retainment in the channel/pipeline.
- Discharge from fish return launder or channel/pipeline should be far enough from water intake to avoid the risk of returned fish re-entering the intake;
- Turbulence within any fish sampling or holding facility should be optimised to reduce the risks of fish exhaustion and injury;
- Shear stress and turbulence should be optimised throughout the system;
- Provision should be made to allow discharge from the high-pressure backwash via the fish return launders. At times when it is mostly weed and debris that are removed at the high pressure wash stage, the material can be diverted for disposal off site;
- At coastal sites where there is a risk of occasional inundation by schools of pelagic fish, provision may need to be made for diverting the catch to collecting baskets;
- Permission conditions may require provision of facilities within the FRRS return channel/pipeline for collection and condition monitoring of live fish.

It may be permitted to return to the sea any debris entering the cooling water system flow via the intake, provided that it is discharged in a continuous stream and not accumulated and discharged at intervals. This may have ecological benefit, as natural biological material is returned to the marine ecosystem.

Coarse bar screens would also be incorporated into the intake head design, preventing larger debris and organisms including marine mammals from entering the cooling water system.

Measures using light/sound and/or vibrations to deter fish from water intake areas.

Maintaining inlet speeds, in line with best practices in the energy sector, at (≤0.3 m/s) may not in itself be sufficient to minimise the entrainment of fish and other marine organisms by cooling water inlets. Fish are known to respond to visual signals generated by infrastructure [147], however, during the night hours or during periods of high turbidity, visual signals can be significantly reduced, leading to an increased likelihood of fish entrapment in water intakes. However, a number of mitigation measures may be included at the design stage of the Project to minimise the entrainment of fish in water intakes, including non-physical (behavioural) barriers designed to deter fish from intake areas and a fish recovery and return system.

Behavioural stimuli can use light, sound, and/or vibration to deter fish from inlets and minimise the possibility of entrainment [82], [134]. Their effectiveness depends on the properties and strength of the signal, the species of fish, the life stage and environmental conditions [82].

Both strobe lights and acoustic deterrents have been shown to be effective for many species [48], [58], [80], [81].. Acoustic Fish Deterrents, known as AFDs, have been shown to deter both species specialised in hearing, which have anatomical structures connecting the swim bladder to the inner ear (e.g. fish from the herring and carp families) [94], [95], [115], and hearing species that do not have such organs, such as salmonids [17], [47], [55], [54].. The advantage of behavioural deterrents is that they are not prone to being blocked by debris or reduction of flow rate. However, although acoustic deterrent devices are used for estuary and coastline intakes, they have never been used in the marine environment (up to 6 km into the sea) or deeply submerged (approximately 25 m deep). The use of an acoustic deterrent system in such conditions would therefore require the development of an innovative methodology for maintaining the system.

Hybrid technologies, combining e.g. light with acoustic devices, are considered to provide the highest level of deterrence [134], [135] and have been installed in estuary cooling water intakes at sites such as the Pembroke Power Station in south-west Wales, UK.

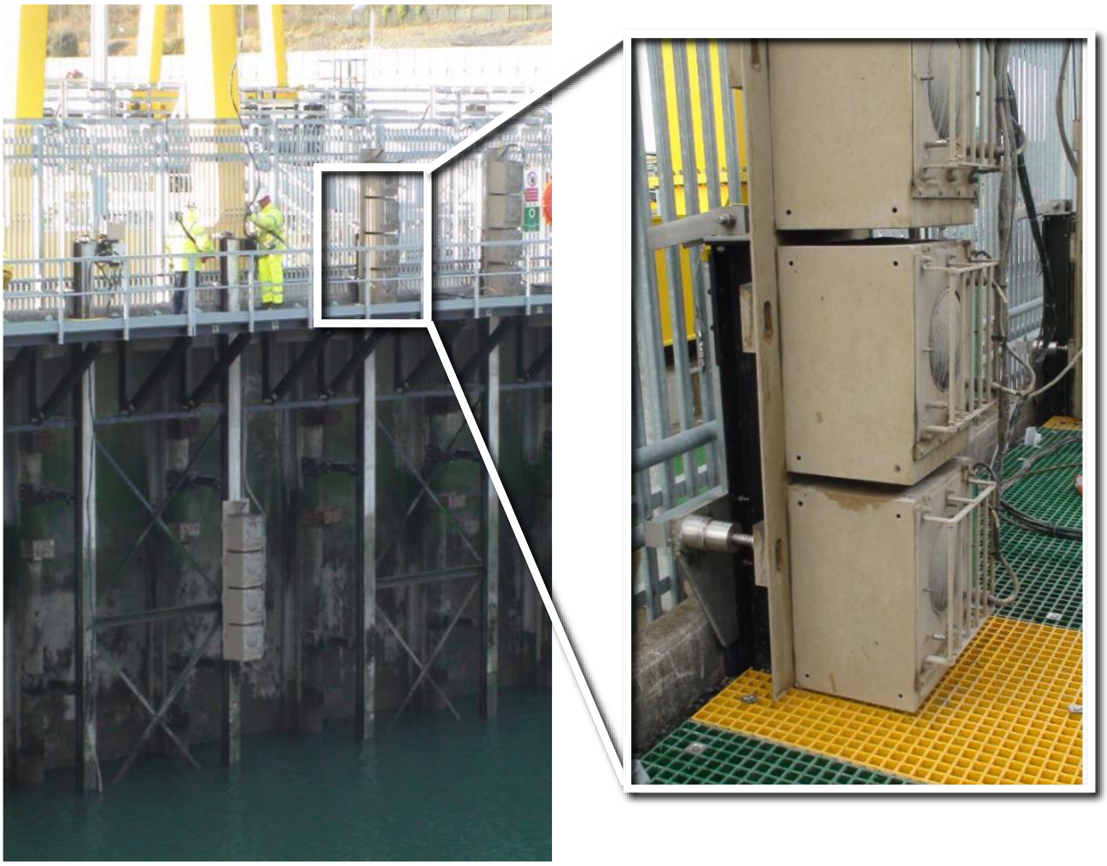


Figure V.3- 1 Fish guidance system installed at Pembroke Power Station, UK
Source: [134],

In line with best practice in the UK, the complementary benefits of installing both behavioural deterrents and a fish recovery and return system for their protection in power plants with a single-flow cooling system using seawater have been demonstrated [127].

Minimising the impact on seabirds

Although the ports and the level of vessel traffic associated with the construction of the marine off-loading facility and wastewater treatment plant are not known at the moment, a marine traffic zone (MTZ) of about 1 km in width will be established in order to minimise the disruption caused by the movement of sea vessels. All vessel approach activity would be restricted to the MTZ which would either take the shortest route through the Special Protection Area Przybrzeżne wody Bałtyku PLB990002, i.e. perpendicular to the coastline and extend 1km in width from the centre-line of the construction or operation footprint or follow the least sensitive route if applicable following results of any supportive surveys. Based on the knowledge regarding the greatest flush distance for the common scoter *Melanitta nigra*, it is assumed that the maximum extent of impacts will be around 1km on both sides of the MTZ area.

To ensure the MTZ is effective at minimising impacts, an adaptive monitoring and mitigation strategy would be developed and implemented before commencement of the development stage of the Project. This strategy would combine desk-based studies with habitat and species distribution and abundance data to refine the location, extent of justification of any MTZ.

Regardless of the above solutions, as part of minimisation activities for the identified components of the environment, the following are additionally proposed:

- Cooperation with representatives of the fisheries sector and keeping them informed on work in progress, including the monitoring of impacts related to increased traffic at sea;

- Co-financing of fish stocking as part of compensation for environmental losses caused by the NPP construction.

V.3.1.5 Marine surface water

The assessment of the impact of the planned Project on marine surface water shows that most of the activities during the construction and operational phases of the Project will not have a negative impact on marine hydrodynamics and geomorphology, seawater quality or biology. However, for some activities in the operational phase, it will be necessary to apply minimisation activities that will avoid significant negative impacts on the environment. The implementation of Sub-variant 1A of the Project will not have a negative impact on the current status of water bodies within the meaning of the WFD and Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive, MSFD) [24] in the case of coastal and marine water bodies, provided that the minimisation measures described below are implemented. It was also stated that the implementation of the Project would not jeopardise the achievement of future objectives regarding the achievement of good surface water status/good environmental status in these water bodies. Below is a proposal for minimisation measures according to the identified pressure in the operational phase.

V.3.1.5.1 Construction phase

There is no negative impact on marine hydrodynamics and geomorphology, seawater quality or biology in the construction phase, therefore no minimisation measures are proposed.

V.3.1.5.2 Operational phase

- **Use of biocides to combat biofilm formation in major condensers, heat exchangers and other components of the cooling water system**

The addition of biocides (chlorine dosed as hypochlorite or produced *in situ* by electrochlorination) may be necessary to combat the phenomenon of biofouling in major condensers, heat exchangers and other elements of the cooling water system in order to prevent the formation of a biological film (precursor to the settlement of mussel larvae and barnacles) and consequently the deposition and growth of living organisms that may restrict flow.

The demand for chlorine in surface water in natural conditions shows geographical diversity. The assessment of chlorine concentration in seawater involves the use of simple laboratory tests to determine the chlorine demand using local water samples. Therefore, it is advisable at the building permit design stage to conduct surveys that would make it possible to determine the rate of chlorine decomposition in the low-salinity waters of the Baltic Sea, both in summer and winter, and to obtain realistic decomposition rates (decomposition coefficient - ko), which can then be included in the modelling of hydrazine flow. Subsequently, it is recommended that the modelling of dilution and dispersion be repeated taking into account the realistic decomposition coefficient (hydrazine spread modelling performed as part of the impact assessment of the Project assumes no decomposition of the substance). Re-modelling at the design stage would reduce the range of impact by making the results more realistic and, at the same time, it would show the amount of chlorine doses that can be used, given the required environmental standards.

Owing to the use of modern systems for controlling (real-time measurement) chlorine concentration in the cooling system, it is possible to optimise the operational protocols for the use of biocides. It is also possible to combine the process with other methods of controlling the phenomenon of biofouling, which would allow discharges to be achieved that are acceptable for the natural environment, with concurrent necessary control of the phenomenon of biofouling.

If the tests of chlorine concentrations in water described above showed that the use of chlorine at the site under consideration is insufficient to satisfy the operational requirements of the power plant, other effective methods of controlling the phenomenon of biofouling (biofilm) [124] are available, which include:

- addition of surfactant-based antifouling products to the cooling water stream,
- physical cleaning of condenser tubes with sponge balls,
- pipe pigging/cleaning device,
- application of smooth and self-polishing coatings,
- use of antifouling paints.

Adopting the approach described above as a minimisation action will ensure that there is no negative impact of the Project in the above respect on the marine environment.

- **Minimisation of hydrazine concentration**

Based on the data provided by the AP1000 reactor manufacturer, there may be a risk of hydrazine concentrations in water discharged from cooling systems during the operational phase. At the same time, it should be emphasised that the abovementioned data does not reflect specific, operational local conditions, which are the basic element determining the possibility of exceeding the concentration limits for the substance in question. At this stage of the project, it is not possible to determine the precise hydrazine concentrations in discharged wastewater. This is due to the fact that the technological details are not yet known, and the feed water treatment schemes are being developed together with the suppliers of the cooling system at the building permit stage.

In the NPP unit, the water circuits in the cooling system require virtually complete removal of oxygen from the feed water, which is not ensured by the thermal degassing method. For the complete removal of oxygen, chemical deoxidation is carried out. Chemical deoxidation of feed water involves the dosage of strong reducers that chemically bind oxygen to it. The effectiveness of this deoxidation depends on the type and dose of the reducer, the pH and temperature of the water, the concentration of dissolved oxygen and the presence of oxidants other than dissolved oxygen in the water. For the chemical deoxidation of water, hydrazine is used that is introduced into the feed water upstream of the feed pump in an amount of not more than 0.18 g per 1000 kg of water. At temperatures above 270ºC, hydrazine completely breaks down, as a result of which NH_3 ammonia is one of the products. Therefore, the hydrazine content in discharges from the cooling system is estimated as being below the limit of quantification.

Essentially, most hydrazine discharges from the NPP will come from the steam generator system blowdown, since the hydrazine used in the reactor coolant, as explained in the paragraph above, is largely destroyed by elevated temperature before release.

Hydrazine is used as a standard in Poland in conventional power plants, where the value of environmental quality standards for toxicity caused by its concentration is not exceeded.

<u>Sequence of minimisation activities</u>

It is recommended that the following hierarchy be followed when considering measures to mitigate the effects of hydrazine discharges:

1. the use of precise dosing of hydrazine into the steam generator system to ensure low residual concentrations in the blowdown, due to:
    - the reaction of hydrazine with oxygen in steam generators, as a result of which nitrogen and water are formed (this is the purpose of adding hydrazine),
    - the decomposition of hydrazine to ammonia in steam generators and high-pressure heat exchangers;
2. investigating the share of hydrazine decomposition in seawater and neutralisation by biocides in reducing residue concentrations in process effluent discharges;
3. if, after the implementation of the treatment referred to in point 1) above and taking into account the decomposition and neutralisation processes quantified in the treatment referred to in point 2), residual

concentrations are expected to occur that give rise to concern, treatment of hydrazine-containing wastewater streams should be ensured prior to their discharge.

Optimisation of hydrazine dosing

Thanks to precise real-time measurements of the level of dissolved oxygen in the coolant carried out at designated sampling points in the steam cycle, hydrazine dosage can be precisely adjusted to ensure effective oxygen absorption, with excess hydrazine being destroyed by heat before blowdown discharge.

At the building permit design stage, it will be necessary to develop detailed operational protocols in cooperation with plant suppliers to allow the prediction and minimisation of residual hydrazine concentrations in wastewater.

Hydrazine decomposition in the waters of the Baltic Sea

Hydrazine will decompose naturally in seawater; however, the speed of decomposition will depend on the composition of seawater. Therefore, in order to take this aspect into account in impact assessment, in situ laboratory studies of the rate of decomposition of hydrazine concentrations in the Baltic Sea water in the area of the considered site will be necessary. The decomposition of the substance into non-reactive derivatives begins immediately after mixing the hydrazine-containing effluent streams with seawater. Therefore, the hydrazine decomposition process will result in virtually complete neutralisation of hydrazine concentration at the point of discharge at the end of the sea discharge channels/pipelines, leading to its elimination at the point of discharge.

Hydrazine neutralisation with biocides

In general, hydrazine is a very strong reducer (therefore it is used to deoxidise feed water), and the biocides (e.g. hypochlorite) added to the water discharged into the sea are strong oxidants, so their addition will cause the decomposition and neutralisation of hydrazine. Hydrazine can be treated and destroyed by oxidation with hydrogen peroxide (using a copper catalyst) or chlorine/hypochlorite [14]. Therefore, another possible treatment to reduce the concentrations of hydrazine and at the same time biocides in cooling systems is to combine industrial wastewater streams on site in such a way that the residual concentrations of hydrazine would be reduced to the required concentration limits by reacting with a biocide. At the construction design stage, the phenomena described above should be analysed and, if necessary, operational protocols should be developed, taking into account the biocide application method, the regimes for discharging process wastewater, including installation blowdown, taking into account the retention time in discharge pipelines and channels.

Treatment of individual wastewater streams

If a sufficient reduction of hydrazine concentration could not be achieved through the application of the measures described above, additional treatments would be necessary. This action would involve the need to apply appropriate hydrazine reduction to individual effluent streams containing hydrazine, mainly regular discharges of steam generator system blowdown through the waste water system (WWS), but also including possible discharges of treated reactor coolant through the liquid radwaste system (WLS) monitor tanks.

In the light of the above, given the availability of possible minimisation solutions to meet the environmental quality standards in terms of hydrazine concentration in the discharge, it should be concluded that the implementation of the necessary measures to mitigate hydrazine discharges will result in limiting the impact to an insignificant level.

- **Minimisation of corrosion products**

It is possible that effluents entering the WWS and WLS wastewater streams may contain heavy metal contaminants resulting from corrosion in the NPP cooling systems. Typically, these include chromium, copper, iron, manganese, nickel and zinc, with the concentration of these components depending on the materials used in the steam generator, condensers and other plant components. Many of them come from the steam generator system, and the concentrations depend on the design of the steam generator, the blowdown system adopted and the technology of blowdown treatment, recovery and recirculation into the feed water system. This has an impact on the composition of the effluents discharged by the WWS. Corrosion products may also be present in coolant discharges from the reactor and from other plant, carried off by the WLS. Other pollutants may occur as a result of contaminants in the chemicals used (e.g. cadmium, mercury), but this can generally be avoided by selecting suppliers accordingly.

The described issues should be analysed at the building permit design stage . If this analysis indicated the need to reduce the concentration of heavy metals in the cooling water discharge in order to ensure that there is no significant adverse impact on the environment, it would be necessary to apply additional treatment of the relevant wastewater streams. Treatment methods are readily available, which mandates the conclusion that, provided that they are used if needed, metal discharges will not have a significant impact on water quality. Based on the experience from other NPP sites around the world, dilution by cooling water flow is predicted to be sufficient to achieve environmental quality standards for heavy metal pollution.

<u>Treatment methods</u>

Metals can be removed from the system by various standard treatment methods, e.g. commonly used chemical precipitation (usually using lime) or with the use of ion exchangers. In order to minimise capital costs and waste production, the treatment should be targeted at the specific wastewater streams containing elevated concentrations of metals, for example wastewater from the steam generator system (SGS).

- Lime precipitation

Lime precipitation is one of the most commonly used methods of metal removal from industrial wastewater because it provides effective treatment and lime is usually readily available and less expensive than other alternative chemicals. Lime treatment involves the removal of metals in the form of their hydroxides by adding lime, followed by their settling. Coagulants (such as iron^{III} salts) and polymeric flocculants can be added to facilitate the separation of the sludge produced. A final sand-bed filtration stage can be added. This approach to treatment results in the formation of solid sludge containing the removed metals, which would require the implementation of a method of sludge removal.

- Ion exchange treatment

Alternatively, metals can be effectively removed by ion exchange treatment. This also creates waste that needs to be disposed of, whether in the form of spent regenerative liquids or disposable resin cartridges if regeneration is not practiced. The metal pollutants from the nuclear island arising from corrosion would in any case be largely removed in the ion exchange processes used to remove radioactivity from the wastewater from the liquid radwaste system (WLS). The treatment efficiency should be confirmed when the effluent is retained in monitor tanks prior to discharge on a batch basis.

- **Minimising the extent of thermal anomaly**

Discharge heads/diffusers in the form of “duck beaks” are designed to be elevated above the seabed with the discharge apparatus directed northwards parallel to the bottom so as to take advantage of the phenomenon of increased displacement of liquids with a higher temperature and lower density than the surrounding water of the receiving waters. Directing discharges this way makes it possible to eliminate the possibility of the thermal anomaly spot “hugging” the shore and extends the path that the heated liquid must travel from the point of discharge from the diffuser in the water column to the surface, thus minimising the extent of the anomaly manifested by the increase in temperature on the water surface.

- **Monitoring of process wastewater discharges**

Wastewater arising from the nuclear island radwaste system (WLS) include process chemicals arising from blowdown from the reactor coolant system (RCS). Full details of process wastewater discharges are presented in Volume II [124].

Effluent flows from the WLS are held in monitor tanks, to allow checks to be made to ensure that levels of radioactivity are within permitted limits before discharge. If not, the wastewater is recycled through the radwaste treatment processes. The monitor tanks would be fitted with variable-speed discharge pumps to allow maximum control over the rate of discharge to sea, in admixture with the cooling water discharge. This would also allow improved management of discharges of non-radioactive components of the effluent, so that compliance with regulatory standards can be ensured.

V.3.1.12 Human health and life

This chapter proposes actions to minimise the impact of the Project on human health and life, taking into account the impact on the quality of life in the areas indicated below.

V.3.1.12.1 Radioactive substances

- **Ionising radiation**

International standards of radiological protection, including Polish regulations, are based on the concept of minimising exposure to ionising radiation. This is an optimisation principle which is commonly referred to in the world as the ALARA (as low as reasonably achievable) or ALARP (as low as reasonably practicable) principle. This principle provides that human exposure to ionising radiation and contamination of the environment by radioactive substances should be limited to levels as low as reasonably achievable, taking into account economic, social and health factors [146]. This means that the operator of a nuclear power plant is legally obliged to introduce such technical solutions that will minimise the radiological impacts according to the ALARA optimisation principle. These solutions have been fully incorporated into the technical solutions of the nuclear power unit with the AP1000 reactor.

- **Safety of food - sea products - in relation to the discharge of liquid radioactive substances**

Minimising liquid emissions to a level as low as reasonably achievable, in accordance with the radiological protection standards in force in Poland and in the world. This will be additionally controlled by radiation monitoring located both in the NPP area and in its surroundings.

- **Safety of food - sea products - in relation to the use of chemicals in the cooling water system**

Minimisation with regard to the discharge of cooling water with chemicals is described in this chapter in the context of the minimisation of impacts on marine surface water [Chapter V.3.1.5.2].

- **Safety of food other than seafood with regard to the emission of gaseous radioactive substances**

Minimising gaseous emissions to a level as low as reasonably achievable, in accordance with the radiological protection standards in force in Poland and in the world. This will be additionally controlled by radiation monitoring located both in the NPP area and in its surroundings.

V.3.1.12.2 Quality of life of the local communtiy

Construction and operational phases

- Development of a Construction Stakeholder Engagement Plan (SEP), the aim of which would be to increase stakeholder engagement at each stage of the Project. The above plan will specify the actions that will be implemented to manage and increase stakeholder engagement. The plan would be developed for the construction phase and it would support the preparation and transmission of up-to-date information about the Project, including information on the technical and technological solutions taken into account, control measures taken, actions taken to minimise impacts and actions to prevent the occurrence of accidents; the personnel influx schedule, the activities of local information centres, the results of monitoring for emissions into the air and the acoustic environment;
- Conducting annual opinion polls to assess the public perception of the Project, in order to assess the quality of the information provided;
- Opinion polling on the local community’s concerns;

- Implementation of a mechanism for reporting complaints, concerns or requests for additional information about the Project, which should help control its perception;
- Development and implementation of a mechanism for complaints relating to the Project from the local community;
- Application of solutions temporarily reducing nuisance or destruction arising from the implementation of the Project or financial compensation of the consequences of the physical execution of the Project (e.g. damage related to construction).

V.3.1.12.3 Availability of recreational areas

Construction phase

- Establishing cooperation with representatives of the site commune and the neighbouring communes to discuss the impact on the areas currently used for recreation and the possibility of access to alternative recreational areas, including their adaptation for use by senior citizens, people with disabilities, and children;
- Carrying out activities for the development and improvement of local cycling routes and pedestrian pathways;
- Providing information about restrictions on access to the coast and land for the local population (their duration, availability of alternative routes, etc.) as part of the Stakeholder Cooperation Plan to be developed for the purposes of the Project;
- Developing and implementing a complaints handling system that can also be used for the submission of concerns or complaints about restrictions on access to land and coast;
- Using the results of the annual public opinion poll to determine the extent of local concerns related to restrictions on access to particular areas. The results would be used under the Project to improve the existing solutions for access to alternative areas.

Operational phase

The minimisation measures adopted during the operational phase will be the same as those applied during construction, and an annual public opinion poll is to be used to identify areas where improvements can be made in access to sites located in alternative locations.

V.3.1.12.4 Road traffic control and safety management

Construction phase

- Cooperation with road management authorities/entitites;
- Optimising the number of journeys of vehicles used for the transport of building materials and personnel (including from the employee accommodation base);
- Using rail transport;
- Implementing a vehicle and driver check system;
- Developing a Traffic Management Plan and appropriate signage in connection with the NPP Project;
- Developing and implementing an emergency response plan for road or maritime emergencies (in close cooperation with relevant authorities and units);
- Establishing reduced speed zones/road sections in the vicinity of places of social significance (i.e. kindergartens, schools, places of worship, recreation etc.);

- Notification of changes in the road traffic management, i.e. temporary road closures and changes in traffic management;
- Carrying out, in cooperation with competent authorities and units, campaigns for the safety of public transport;
- Implementing a complaints handling system, through which residents will be able to report cases of reckless behaviour of drivers of vehicles used for the purposes of the Project;
- Active participation in the communication of information on temporary changes in the road system to emergency services, so that response teams can modify routes along major roads accordingly; emergency response coordination centres and ambulance drivers will be fully informed of any road works and changes in traffic organisation, well in advance of their introduction;
- Development of a programme on the possibility of using dedicated transport resources enabling the transport of large numbers of employees in order to reduce the movement of vehicles.

Operational phase

The minimisation measures implemented during operational phase would be the same as those applied during construction, and updated before the start of the operational phase and modified to take account of any experience gained during the construction phase.

V.3.1.12.5 Provision of healthcare

Construction phase

- Preparation and implementation of an HSE/BIOZ plan, based on risk analysis in order to reduce the risks to workers' health and safety so that they are reduced to an ALARP level, i.e. as low as reasonably practicable;
- As part of the Project, an anti-drug and alcohol policy is to be implemented as well as a random testing programme;
- Employees are to undergo the required medical examinations for admission to work, which, if necessary, would be extended to include infectious diseases; in addition, at the nuclear commissioning stage, employees would be subject to radiological protection standards and related medical examinations for the absence of contraindications to working under exposure to ionising radiation (which is decided by an occupational medicine doctor with appropriate qualifications);
- Dedicated occupational medicine service and other medical services can also be provided in the analysed area, as well as at the employee accommodation facility (associated infrastructure), in which a medical centre will also be set up to reduce the demand for healthcare services provided to the general local community.

Operational phase

The minimisation measures implemented during operational phase would be similar to those applied during construction, and updated before the start of the operational phase to take account of any experience gained during the construction phase. Minimisation measures related to exposure to ionising radiation would include a health care system for NPP employees, an on-site dosimetric system (dose measurements for personnel) and radiological monitoring of the NPP environment.

Changes in the health services provided will primarily concern NPP employees, who will be subject to regular medical examinations. These examinations are required by Polish radiological protection regulations. These include, among other things, blood tests, ophthalmological examinations and occupational medicine examinations.

V.3.2. Compensation

V.3.2.1 Natural environment

In the context of nature compensation necessary to ensure the cohesion and proper functioning of the network of Natura 2000 sites under Article 34 of the Nature Protection Act [138], and having regard to nature compensation according to Article 75 of the EPL Act [141], no need for its implementation was found. The minimisation measures presented above for biotic components of the environment are believed to be sufficient to minimise potential significant negative impacts on the biotic environment arising from the Project.

V.5 Analysis of potential social conflicts

V.5.5 Communication activities

V.5.5.3 Operational phase

Objective:

- informing about the results of the environment monitoring carried out,
- informing of the safety and nuclear threats,
- gathering information on the Project's impact on local, regional, and national social, environmental, and economic conditions.

Planned activities:

Irrespective of the information activities undertaken locally by the Local Information Center, the nuclear power plant operator shall provide anyone, regardless of their actual or legal interest, with written information on the status of the nuclear facility, its impact on human health and the environment, and the magnitude and isotopic composition of releases of radioactive substances into the environment. Under the Atomic Law [146], the operator is obliged to publish such information on its website at least once every 12 months. Moreover, the NPP operator is obliged to forthwith provide the President of the PAA, the voivode, the poviat authorities and the authorities of the commune where the nuclear facility is located, as well as the authorities of neighbouring communes, with information on events at the NPP that may result or do result in a hazard. Information on unplanned events that cause a hazard are published by the President of the PAA in the Public Information Bulletin on its websites. The NPP operator shall also make available, on their website, the information on the events that caused a hazard and took place within the period of the last 12 months.

The planned communication activities include:

- the Local Information Center (Article 39m of the Atomic Law) will provide visitors with the opportunity to learn about the operation of the NPP, safeguards, etc.; the LCI will provide nuclear education for pupils and students, lectures, symposia, etc., and will distribute information and educational materials;
- monitoring of the public perception and public information needs through regular opinion polls and continued dialogue with the authorities and the local community;
- monitoring of the condition of the protected areas and objects and evaluating them in accordance with the adopted and published schedule of activities;
- providing informational materials on the activities undertaken by the Investor and on the results of these activities.

V.6 Predicted range of the planned restricted use area

This chapter discusses the issue of legitimacy of establishing a restricted use area (RUA) for the Project planned, including, in accordance with the requirements of the GDOŚ Decision [87], the predicted territorial extent of the area, taking into account permissible annual effective doses from all exposure pathways (including operational states and in case of accident without reactor core meltdown). The boundary of the proposed restricted use area for the Project is shown for the preferred variant to be implemented, including against the cadastral map [Appendix V.6-1].

V.6.1 Regulatory requirements concerning the designation of a restricted use area around the NPP

V.6.1.1 Atomic Law Act

Pursuant to Article 36(f)(1) of the Atomic Law Act [146], a restricted use area is created around a nuclear facility, under the rules set forth in the Environmental Protection Law [143].

The criteria for determining the RUA around a nuclear facility were established as follows:

- **paragraph 2, items 1 and 2**: The RUA includes the area outside of which:
  - in operational states(1), the annual effective dose from all exposure pathways(2) will not exceed 0.3 mSv;
  - in the event of an accident without core melt(3) the annual effective dose for all exposure pathways will not exceed 10 mSv;
- **paragraph 3, item 2**: the estimation of the effective dose shall take into account data and information on the following:
  - site of a nuclear facility (...) taking into account the most unfavourable meteorological(4), hydrological, (...) conditions in the area of the nuclear facility.

(1) in safety analyses, operating disturbances (anticipated operational occurrences) with a probability of occurrence greater than once every 100 years of reactor operation, are also included into operational states,

(2) the phrase "from all exposure pathways" in the annual effective dose criterion for an accident without core melt (Article 36f(2)(2)) implies that the internal exposure via ingestion must also be considered,

(3) accidents without core melt are design basis accidents (category 1 and 2) and complex sequences [83],

(4) the phrase "taking into account the most adverse meteorological conditions" (Article 36f(3)(2)) means that it is necessary to take into account the 100% quantile of meteorological conditions.

According to the legal situation applicable as at the time of preparing the EIA Report, the restrictions arising from Article 36g(1) of the Atomic Law Act of 29 November 2000 [146] should be indicated that pertain to the need to establish the RUA. At the current stage of the Project implementation, there are no premises to determine detailed restrictions on real estate development due the early stage of the Project and the fact that, according to the analyses of the Investor, the obligation to establish the area of limited impact occurs only in the case of the criterion of considering the accident without core melt (Article 36f(2)(2) of the Act of 29 November 2000 Atomic Law [146]), and not on the basis of the criterion concerning the operational states. Possible restrictions related to the development of the real estate in relation to the restricted use area will be determined at the latest at the stage of the post-implementation analysis.

V.6.1.2 Environmental Protection Law Act

The provisions regarding establishing the RUA are included in Article 135(2) and (3a) of the Environmental Protection Law Act. These provisions stipulate that "the voivodeship sejmik (regional assembly), when establishing a restricted use area by way of a resolution [...], determines the boundaries of the area, restrictions in terms of land use*, technical requirements for buildings, and the manner of using the land arising from the proceedings on environmental impact assessment or post-project analysis, or ecological review".*

It should be noted that although the boundaries of the RUA are established by way of a resolution of the voivodeship sejmik (regional assembly), passed at the time of the proceedings associated with obtaining the license to build the NPP, but in order to determine these boundaries a positive opinion of the President of the PAA has to be obtained [87] (Atomic Law Act, Article 36f (4)).

V.6.2 Results of the RUA extent analyses

In order to determine the predicted extent of the RUA, taking into account the requirements of the GDOŚ Decision, variant calculations and analyses of the RUA extent around the NPP were performed.

The annual effective dose criteria applied at the RUA boundary are described in detail in [Chapter IV.14] and [Chapter IV.18]. These criteria relate to the radiation impact of the NPP on the surrounding area:

- in operational states (annual effective dose: 0.3 mSv): A1.1 (RUA1),
- in the event of an accident without core melt (annual effective dose: 10 mSv): 4 variants of sub-criteria - from A1.2-1 (RUA2_1) to A1.2-4 (RUA2_4).

The calculated RUA extent is determined by the radiation impact of the NPP in the event of an accident without core meltdown, and the sub-criteria variants adopted for calculation and analysis result from a combination of the following assumptions:

- Including, or not including, internal exposure through ingestion in annual effective doses (this assumption has the greatest impact on the results);
- Range of meteorological conditions considered: 100% quantile (i.e., the full spectrum of conditions, including the most unfavorable conditions - even the very short-term ones), or 95% quantile (i.e., discarding 5% of unfavorable conditions - which is consistent with best international practice, including in the USA. [128] and Finland [11]).

Detailed calculation results are presented in a tabular form in Volume IV [Table IV.18-1].

The following sections present the results of the RUA coverage calculations.

- For the operational states of the NPP, the results of calculations and analyses of the RUA extent using the annual effective dose criterion A1.1 (RUA1), i.e., an annual effective dose including all exposure pathways of 0.3 mSv, considering a 100% quantile of meteorological conditions, showed doses below this criterion;
- For an accident without core meltdown, the results of the RUA extent calculations and analyses obtained depend on the criteria used in determining the annual effective dose of 10 mSv, as shown below:
  - Including the annual effective dose of internal exposure through ingestion in the calculation and assuming a 100% quantile of meteorological conditions (sub-criterion A1.2-1 (RUA2_1)) results in a RUA with a maximum extent (distance from the emitter) of 3,521 m for one reactor unit and 3,781 m for 3 units (calculated from the geometric centre of all units).
  - The RUA extent thus calculated, in accordance with the legal status as at the date of the EIA Report, is presented in [Figure V.6- 1];
  - Including the annual effective dose of internal exposure through ingestion in the calculation and assuming a 95% quantile of meteorological conditions (sub-criterion A1.2-2 (RUA2_2)) would result in a RUA with a maximum extent (distance from the emitter) of 1,686 m for one reactor unit and 1,946 m for 3 units;
  - Failure to include the annual effective dose of internal exposure via ingestion in the calculation, even assuming a 100% quantile of meteorological conditions (sub-criterion A1.2-3 (RUA2_3)), would result in a RUA with a maximum extent (distance from the emitter) of only 230 m for one unit (490 m for 3 units) - which means that the boundaries of the RUA so designated would be within the NPP site, so establishing a RUA outside the NPP site would not be necessary;
  - In contrast, failure to include the annual effective dose of internal exposure through ingestion, assuming a 95% quantile of meteorological conditions (sub-criterion A1.2-4 (RUA_4)) showed doses below this criterion.

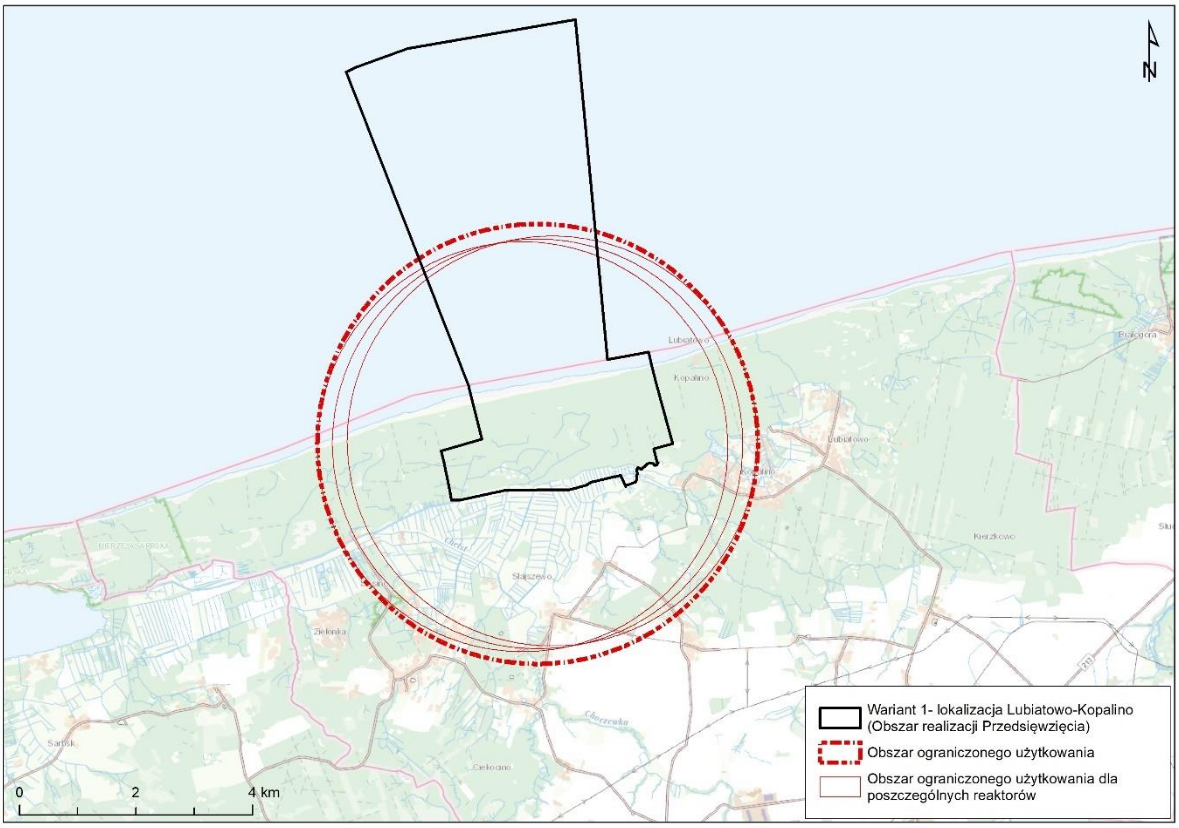


Figure V.6- 1 Restricted Use Area for Variant 1 - Lubiatowo - Kopalino site in accordance with the literal understanding of the provisions of the law
[Legend: Black line – Variant 1 Lubiatowo-Kopalino site (Project Area), Red dotted line – Restricted use area, Brown lines – Restricted use areas for individual reactors]

Source: In-house study

V.6.3 Summary

Assuming fulfillment of the provisions of the Atomic Law Act as at the date of the EIA Report, which are the criteria for the establishment of the restricted use area, for the Lubiatowo - Kopalino site the RUA should be 3,781 m. This distance is calculated from the geometrical center of the line connecting the reactors, and takes into account the results of analyses of releases from each of the three reactors separately. This area is presented in [Figure V.6- 1].

The RUA boundaries will be redefined for the purposes of the Preliminary Safety Report (PSR) and will be performed for the selected NPP design in compliance with the legal regulations in force at that time.

V.7 Proposed scope of monitoring for individual components of the environment

This chapter presents a proposal for the scope of monitoring for biotic and abiotic components of the environment for the ongoing monitoring of potential changes that may arise within the impact range of the Project in Variant 1 – Lubiatowo - Kopalino site, implemented under Sub-variant 1A – open cooling system using sea water. Monitoring is necessary so that at the earliest possible stage of the work it is possible to identify any need for additional intervention or preventive actions, and thus to minimise the impact of the Project on the environment.

Monitoring activities cover the implementation of the Project in the construction and operational phases, without the decommissioning phase. Due to the very distant prospect of a possible decommissioning of the NPP, it is difficult to predict the principles and scope of monitoring. It will be determined at the stage of preparing a separate EIA Report, necessary to obtain an Environmental Decision for the NPP decommissioning phase.

Monitoring for associated projects has not been indicated, as it is to be indicated at the stage of preparing separate EIA Reports and design documentation for these infrastructure components, after a thorough analysis of the impact of these projects. Notwithstanding the above, the scope of monitoring and the manner in which it is carried out would be subject to periodic review in the context of monitoring for associated infrastructure projects.

V.7.1. Natural environment

Presented below is a proposal for the scope of nature monitoring for the purposes of monitoring the impact of the Project, in particular on the forms of nature protection referred to in Article 6(1) of the Act of 16 April 2004 on nature protection [138], including the conservation objectives and qualifying features of a Natura 2000 site, and the continuity of wildlife corridors connecting them.

In order to ensure the reliability of monitoring, methodological guides governing the principles of monitoring for plant species and natural habitats have been developed by a team of specialists and made available by the Environmental Protection Inspectorate. These include: Monitoring of plant species [66], Monitoring of natural habitats [68] and Monitoring of animal species [67]. The methodological guides developed make it possible to ensure that a uniform research methodology is applied by different contractors. It is important that the results should be consistent and comparable, both at the level of survey sites, area, and biogeographical region.

Scope of nature monitoring

In order to achieve effective nature protection, it is necessary to have information about its condition, directions and dynamics of transformation. The most thorough inventory and evaluation of natural values reflects only the status of nature at a given moment, which is the result of human activities. The transformation that occurs depends on the totality of environmental conditions, but is also a consequence of socio-economic impacts. Therefore, thorough nature monitoring, sometimes referred to as biological monitoring, is a necessary condition that enables natural and anthropogenic transformation to be observed taking place in the natural environment, as well as the protection of its individual components. It is an activity consisting in a systematic assessment of the condition of natural environment components, the dynamics of processes taking place in the analysed areas, as well as the reactions of plants, animals or a specific group of fungi under the influence of changes in the abiotic environment. The basic task of nature monitoring is to collect, gather, process and share data on the condition of nature as well as phenomena and processes taking place. This information allows an objective assessment to be made of the transformation that takes place in the natural environment, which arises from the impact of abiotic factors. This is only possible if an area affected by a number of factors can be compared with an area of the same natural value, not subject to such impacts. Such a comparison and the drawing of appropriate and objective conclusions are possible also through monitoring in a reference area. This is therefore the basic assumption that allows a correct assessment to be made.

Monitoring should cover not only populations of all species and all biocenoses of special concern, especially those most threatened with extinction or degradation, but also populations of species of foreign origin, primarily those showing territorial expansion and threatening native species, as well as biocenoses formed as a result of human activity and influenced by human economy. The categories of biodiversity determinants are as follows:

- Ecosystems and habitats characterised by high biodiversity, a large number of taxa specific of the area concerned, threatened or having primal natural features;
- Areas and habitats necessary for migratory species;
- Areas and habitats of significant social, economic, cultural or scientific importance;
- Areas and habitats that are representative, unique, or critical to evolutionary or biological processes;

- Species or their groupings threatened by domesticated wild and famed species;
- Species of particular medical, agricultural or other economic value, including those of social, scientific and cultural importance;
- Species relevant to science and research related to biodiversity and their optimal use, such as indicator species;
- Described genomes of scientific, social, and economic importance.

Without the information collected in this respect, it is not possible to implement international agreements to which Poland is also a signatory. These include, among others: the Convention on Migratory Species, the Bonn Convention and the Agreement on the Conservation of the Population of European Bats (EUROBATS) signed under this Convention, the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBATS), the Agreement on the Conservation of Aquatic Warbler, or the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat.

Nature monitoring in the area affected by the Project and in the reference area should be carried out using comparative methods so that its results reflect the processes taking place. The scope of monitoring should concern both natural habitats, species of flora and fauna that have been surveyed in the Project Area. These will be mainly natural components that are elements of Natura 2000 as well as other forms of protection, including species protection, or rare and endangered taxa on a national and regional scale.

The marine monitoring area would operate on the basis of the same principles as in the case of land area monitoring. What would be an important factor, in addition to biotic elements, represented primarily by animals, are observations of some parameters of the abiotic environment having a significant impact on the fauna. They undoubtedly include a change in the thermal characteristics of water and the level of its oxygenation, which would be affected by interference in the hydrochemical properties of water.

Nature monitoring area

In order to assess the impact of the Project on the natural environment and prevent adverse changes to this environment, nature monitoring should be carried out, taking into account both the Project Area, the environment of the beach, dunes, as well as adjacent areas at a distance of up to 5 km from the boundary of the Project Area. The selection of monitoring areas, as well as the specific monitoring area and its extent, will be prepared as part of nature supervision and presented for information to the competent authority for nature conservation before the start of the development stage.

In addition, in parallel, monitoring activities should be carried out in the reference area, which should be similar in terms of natural resources to the area covered by nature monitoring, carried out to monitor the impact of the Project on the conservation status of habitats and species. When determining the reference area, account should be taken of the availability of historical data for the site and the absence of exposure to possible impacts from other projects carried out or operating in the areas adjacent to the reference area.

Both land ecosystems and, in this case, the marine area must be covered by the monitoring area. In both cases, it is necessary to collect initial information, i.e. to assess the baseline state. This assessment should be carried out as part of monitoring preceding the implementation of the Project.

Reference area selection criteria

The monitoring results obtained for the elements of the environment to be observed and assessed in the reference area must not be subject to any anthropogenic effects. It should be an area where the natural environment is shaped by natural processes. This is a basic requirement for its function. The following are the criteria that should be taken into account when choosing a reference area:

- The occurrence of natural elements that will be monitored in the area affected by factors arising from the implementation of the Project;

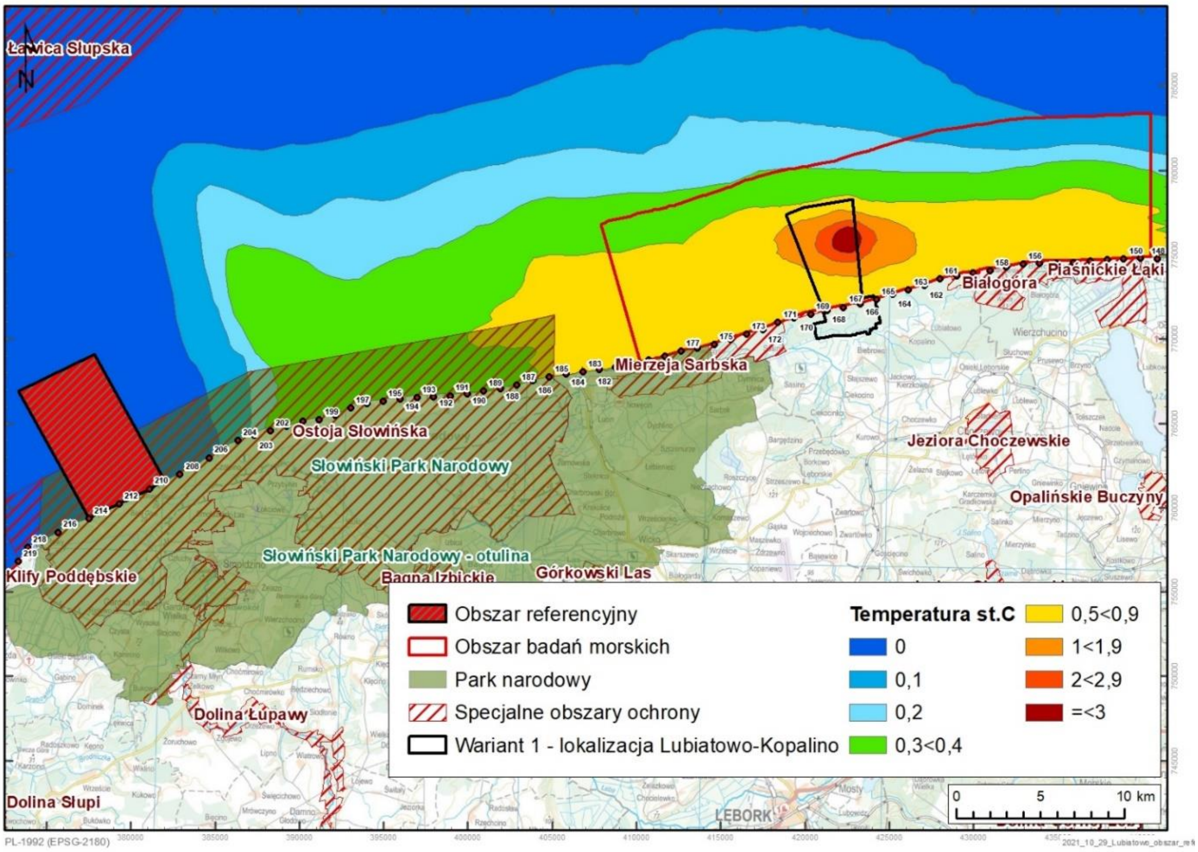
- Care should be taken to ensure that the location of the reference area is not subject, as far as possible, to impacts resulting from any activities affecting the natural state of the environment. This means that transformation in its natural environment should be a consequence of the natural processes that take place in its biochores;
- When choosing a reference area, knowledge of its natural values should also be crucial. This means that its natural resources would be initially recognised both in terms of their natural state and their diversity, as well as in terms of the lack of planned investment activities that would affect it;
- In the absence of any comparative receptor, not registered in the reference area, and occurring in the area subject to the impact of factors arising from the implementation of the Project, it is permissible to select the appropriate natural element in its immediate vicinity. This situation may occur in the case of some taxa of flora or fauna. It is then possible to carry out monitoring activities at the sites of species that have undergone metaplantation. This action will also be mandatory for the taxa transferred as part of the implementation of the minimisation task.

All rules for monitoring in the Project Area and within the impact range, as well as in the reference area are to be determined in accordance with the detailed methodologies and legal acts in force in this respect. They would be the subject of separate studies to be developed as part of nature supervision established before the start of the construction phase.

Reference area proposal for the marine part of the Project

In accordance with the requirements of the GDOŚ decision [87], the marine environmental survey area located outside the impact range of the variant proposed by the applicant, constituting a potential reference area for monitoring the impact of the NPP on the marine ecosystem is indicated below. The reference area has been designated so that the results of the surveys carried out in the reference area can provide information on possible changes in the qualitative and quantitative characteristics of waters and elements of the marine environment as a result of the impact of factors other than those generated by the Project and as a reference point in monitoring and determining the actual impact of the NPP on individual components of the marine environment. In view of the above, the figure below [Figure V.7- 1] shows the location of the reference area concerned, which, according to the assumptions, is to be situated outside the impact range of the variant proposed by the applicant for implementation.

The area in question has been designated between 209 and 214 km of the sea shore. The area is 5 km wide, 8.5 km deep into the sea and has an area of 4,310 ha, which is approximately 1/5 of the surface area of the assumed survey area for Variant 1 – Lubiatowo - Kopalino site. The area is situated to the west of the forecasted thermal impact limit. The figure below shows the location of the survey area in question in relation to the expected impacts from spent cooling water, discharged by means of an open cooling system in the Project Area.

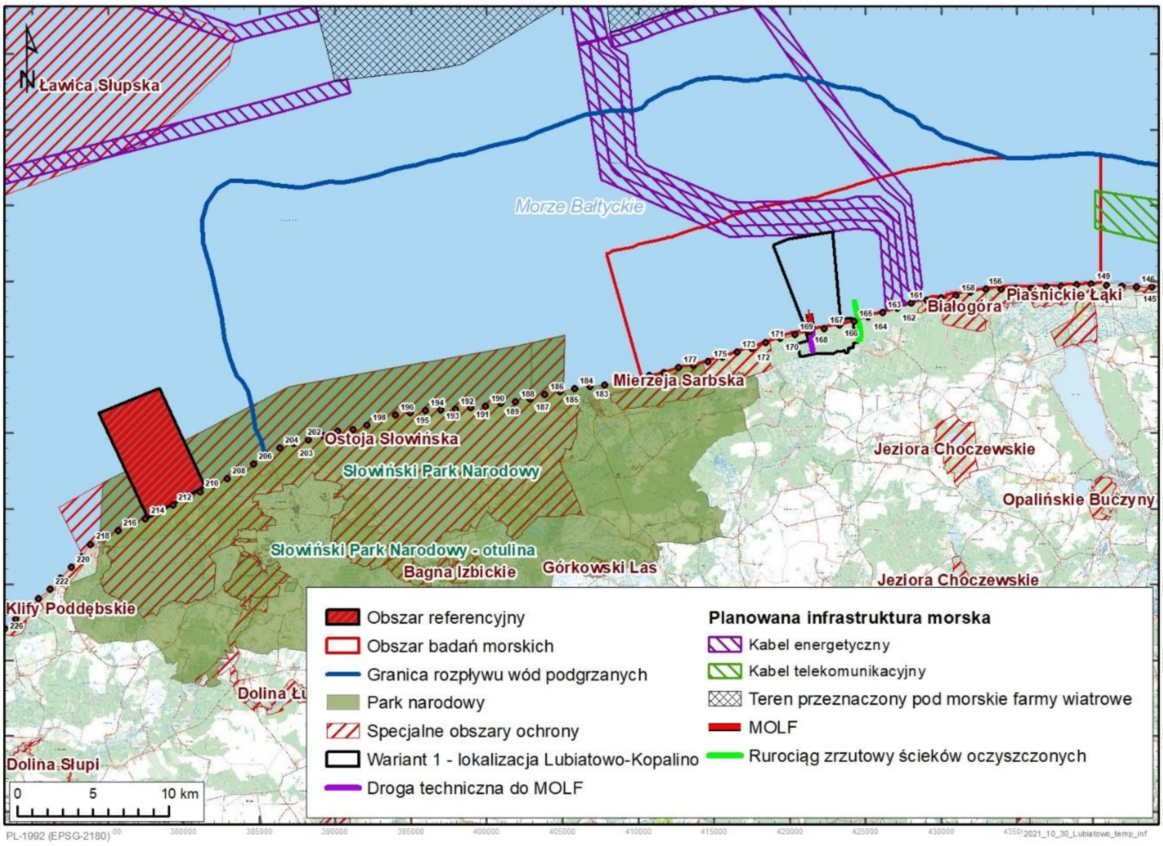


Obszar referencyjny	Reference area
Obszar badań morskich	Marine survey area
Park narodowy	National park
Specjalne obszary ochrony	Special protection areas
Wariant 1 - lokalizacja Lubiatowo - Kopalino	Variant 1 – Lubiatowo - Kopalino site
Temperatura st.C	Temperature (deg C)
Ławica Słupska	Ławica Słupska
Klify Poddębskie	Klify Poddębskie
Dolina Słupi	Dolina Słupi
Dolina Łupawy	Dolina Łupawy
Ostoja Słowińska	Ostoja Słowińska
Słowiński Park Narodowy	Słowiński National Park
Słowiński Park Narodowy – otulina	Słowiński National Park – buffer zone
Bagna Izbickie	Bagna Izbickie
Górkowski Las	Górkowski Las
Mierzeja Sarbska	Mierzeja Sarbska
Białogóra	Białogóra
Piaśnickie Łąki	Piaśnickie Łąki
Jeziora Choczewskie	Jeziora Choczewskie
Opalińskie Buczyny	Opalińskie Buczyny

Figure V.7- 1 Location of the reference area in relation to the impacts of spent cooling water

Source: In-house study

In addition, the reference area has been designated so that it is not in conflict with existing and planned offshore technical infrastructure. The figure below [Figure V.7-2] shows the location of the reference area in relation to the existing and planned offshore infrastructure, i.e. the location of farms from the maritime development plan and studies [6], [8].



Morze Bałtyckie	Baltic Sea
Ławica Słupska	Ławica Słupska
Klify Poddębskie	Klify Poddębskie
Dolina Słupi	Dolina Słupi
Dolina Łupawy	Dolina Łupawy
Ostoja Słowińska	Ostoja Słowińska
Słowiński Park Narodowy	Słowiński National Park
Słowiński Park Narodowy – otulina	Słowiński National Park – buffer zone
Bagna Izbickie	Bagna Izbickie
Górkowski Las	Górkowski Las
Mierzeja Sarbska	Mierzeja Sarbska
Białogóra	Białogóra
Piaśnickie Łąki	Piaśnickie Łąki
Jeziora Choczewskie	Jeziora Choczewskie
Opalińskie Buczyny	Opalińskie Buczyny
Obszar referencyjny	Reference area
Obszar badań morskich	Marine survey area
Granica rozpływu wód podgrzanych	Heated water spread boundary
Park narodowy	National park
Specjalne obszary ochrony	Special protection areas
Wariant 1 - lokalizacja Lubiatowo - Kopalino	Variant 1 – Lubiatowo - Kopalino site
Droga techniczna do MOLF	Service road to MOLF
Planowana infrastruktura morska	Planned marine infrastructure
Kabel energetyczny	Power cable
Kabel telekomunikacyjny	Communications cable
Teren przeznaczony pod morskie farmy wiatrowe	Area intended for offshore wind farms
MOLF	MOLF
Rurociąg zrzutowy ścieków oczyszczonych	Treated effluent discharge pipeline

Figure V.7- 2 Location of the reference area in relation to the existing infrastructure

Source: In-house study

It should be noted that the final confirmation of the selection of the reference area would be possible only at the stage of work on the building permit design and before the start of the development stage. This is due, among other things, to the fact that this area cannot be exposed to impacts from other projects, i.e. not related to the implementation of the Project, as well as associated infrastructure. Taking into account the schedule of numerous investments planned in the Pomorskie Voivodeship, it will not be possible to determine it correctly until before the start of development works. The above assumption also applies to the designation of a reference area for works carried out in the land part of the Project Area.

Monitoring period

Nature monitoring is recommended prior to the commencement of construction works and for a period of five years after completion of construction, i.e. in the operational phase of the Project.

V.7.5. Surface water

V.7.5.2 Inland marine waters

Scope of monitoring

Monitoring of physico-chemical elements

In connection with the drainage of rain and meltwater, as well as water from drainage of construction excavations to the sea, it would be required to monitor marine waters. The scope of monitoring, the minimum frequency of water sampling, reference methodologies of analyses and the method of assessing whether the water discharged into water bodies or into water facilities meets the required conditions should comply with the Regulation of the Minister of Maritime Economy and Inland Navigation of 12 July 2019 on substances particularly harmful to the aquatic environment and conditions to be met when discharging sewage into waters or into the ground, and when rainwater or meltwater is discharged into water bodies or water facilities [97].

Water monitoring (measuring ports) would be provided at the outlet of the water device discharging treated industrial effluent, including spent cooling water, into sea waters. The scope of measurements is to correspond the identified pressures specific to individual phases of the Project. Measurements will be carried out with frequency and according to the reference methodologies given in the above-mentioned regulation.

Monitoring of hydromorphic elements, including beach changes

As part of the agreed adaptive environmental monitoring programme, monitoring of beach and dune profiles would be undertaken. Monitoring would be supplemented periodically and in accordance with the methodology used in previous surveys for the Project. The research methodology would also aim to maintain consistency with the approach to monitoring the sea coast near Variant 1 – Lubiatowo - Kopalino site, conducted as part of the "Coastal Protection Programme" for the years 2004-2023. Beach nourishment and/or flood protection strategies would be agreed in accordance with erosion thresholds, in consultation with the Maritime Office in Gdynia and based on the envisaged initial processes shaping the coastal zone.

The purpose of the monitoring would be to confirm the predictions that there would be no significant impact on the coastal protection requirements resulting from construction works carried out at sea and the long-term presence of marine and coastal structures, or define the required coastal protection measures, allowing their implementation in order to avoid significant negative impacts. This would only be required if the open trench/immersed tube method for the construction of the cooling water intake and discharge tunnel is chosen. If a tunnelling or horizontal directional drilling (HDD) approach is chosen, the Project would avoid any potential impact on the stability of the coastline and in this case no monitoring would be required.

Monitoring period

Monitoring should be carried out throughout the construction period and continued during the operational phase, while the scope of monitoring should be modified in accordance with the implementation phase of the Project.

V.7.8. Ionising radiation

Radiation monitoring [28], i.e. constant measurements of dose rates or doses of ionising radiation and concentrations of selected radioactive substances, is a routine activity in every nuclear power plant. Due to its location, radiation monitoring would include:

- **on-site radiation monitoring**, which includes [28]:
  - source monitoring: measurements of emissions/discharges of radioactive substances into the environment in gaseous, aerosol or liquid form,
  - radiation monitoring of the environment in the power plant (within the boundaries of the facilities and the power plant itself),
  - monitoring of individual exposure of workers to ionising radiation,
- **off-site environmental radiation monitoring.**

Depending on the stage of life of a nuclear power plant, the following stages of radiation monitoring are distinguished [28]

- **pre-operational monitoring /studies** – according to the nomenclature of the International Atomic Energy Agency, pre-operational monitoring is started a minimum of one year or [57] recommended 2-3 years [56] before commissioning the power plant, followed by proper operational monitoring, which is carried out from the moment the nuclear reactor is commissioned (pre-operational monitoring essentially does not differ in terms of scope from operational monitoring),
- **monitoring in the operational stage**.

1) <u>On-site radiation monitoring</u>

- **Source monitoring**

As part of “source monitoring” of emissions/discharges of radioactive substances into the environment, online monitoring is conducted and gas samples are taken from:

- the main plant vent through which volatile radioactive substances (mainly short-lived) are discharged into the atmosphere, predominantly radioactive noble gases,
- rainwater reservoirs,
- a pipeline through which rainwater is discharged into the environment.

- **On-site environmental radiation monitoring**

On-site environmental radiation monitoring of the NPP can be categorised into:

- monitoring of the Nuclear Power Plant site itself (within the perimeter of the plant fencing),
- monitoring inside the power plant facilities (reactor building and other facilities where radioactive substances are located). It involves, among other things, regular sampling of process media (mainly water) from selected points in systems and facilities of the Nuclear Power Plant, including water from external cooling circuits discharging heat into the environment, or water from nuclear fuel pools (fresh and spent). These samples are then subjected to in-depth radiochemical and spectrometric analysis to estimate the concentrations of selected radioactive isotopes, in particular nuclear fission products, neutron activation products in the reactor core, erosion and corrosion products of nuclear steam supply system construction materials, as well as isotopes of uranium, plutonium and other transuranic elements. This system is complemented by a network of ionising radiation (alpha, beta, gamma, and, inside the reactor building, also neutron) dose rate detectors, which continuously provide information on the current level of radiation. A detailed monitoring plan inside the reactor building is established by the operator of the

nuclear power plant and accepted by the nuclear regulator (President of the PAA) usually as early as the power plant design stage.

On 2 August 2021, a draft (dated 30 July 2021) Regulation of the Council of Ministers on the scope of the environmental radiation monitoring programme developed and implemented by organisational units classified under hazard category I or II [89] was published (for public consultation). At the moment (i.e. November 2021) there are still no relevant regulations in Poland on radiation monitoring of nuclear facilities such as the NPP, although they are expected to be issued in the near future. This Regulation will implement the requirements of Council Directive 2013/59/EURATOM of 5 December 2013 [26] laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. The draft regulation [89] concerns radiation monitoring both in operational states and in the event of a nuclear accident or radiological emergency. A summary of the draft Regulation can be found in [Appendix V.7-1].

On the basis of the draft regulation [89], it is possible to define the general scope and requirements for radiation monitoring, both on-site and off-site, although a detailed monitoring programme is developed and implemented in each case by the organisational unit concerned, in this case by the operator of the Nuclear Power Plant. The basic elements of radiation monitoring of the environment at the Nuclear Power Plant (on-site), which the monitoring programme is to take into account, therefore include:

– automatic measuring stations: continuous measurement of gamma radiation dose rates together with parallel measurement of its spectrum (to determine radioactive isotopes in the air). In addition, the station should be able to measure meteorological conditions, i.e. the amount of precipitation, temperature, wind (force and direction), pressure and humidity. At least two stations are assumed to be installed at the Nuclear Power Plant site,
– active dosimeters: measurement of the gamma radiation dose rate once every two months by devices located at a minimum of four points at the Nuclear Power Plant site, usually equipped with one real-time detector (e.g. a Geiger-Mueller tube),
– passive dosimeters: at least eight points at the Nuclear Power Plant site where passive dosimeters are located – usually of the thermoluminescent (TLD), or optoluminescent (OSL) type. The advantage of such a solution is a much higher sensitivity than for Geiger-Mueller active dosimeters, while the disadvantage is the monthly or quarterly cycle of reading the dose counted from the entire measurement period. It is worth adding, however, that both systems, active and passive, complement each other well,
– atmospheric aerosol sampling point: a measuring device (or a set of devices) using a filter and the deposition on the filter of atmospheric aerosols from pumped air, used to measure (with very high sensitivity) concentrations of selected radioactive isotopes, such as tritium, isotopes of strontium, carbon, krypton, xenon or plutonium, as well as total beta and alpha activity in the air,
– in-situ deposition and dry and wet radioactive fallout points: points for sampling and further analysis of selected radioactive isotopes that have settled naturally on horizontal surfaces, e.g. selected isotopes of caesium, iodine, cobalt, strontium and plutonium, as well as total beta and alpha activity (for radioactive fallout measurements),
– soil sampling points: as above, but this concerns the collection and isotopic analysis of soil samples taken from the NPP site, for the monitoring of selected radioactive isotopes, such as caesium, strontium, plutonium, carbon, uranium, tritium and total alpha and beta activity,
– water intake points: through drinking water intakes (water pipes), drainage water and groundwater (piezometers) at the power plant. Isotopic measurement similar to soil samples, but complemented with dose rate, gamma and radon emitters, etc.,
– sampling points for other bioindicators: tests of the radioisotopic composition of grass samples from the power plant site and food from the company canteen, by analogy with the previous points.

- **Monitoring of individual exposure of workers to ionising radiation**

On-site radiation monitoring should also include monitoring of individual exposure of employees (power plant personnel as well as external personnel, e.g. subcontractors). Each person working under exposure to ionising radiation is required to perform routine dose checks by using personal (individual) dosimeters, which are read by a dosimetric laboratory accredited for activities in accordance with ISO 17025, at least once a quarter. In a special case, so-called environmental dosimeters may be used to measure the spatial dose equivalent, $H^*(10)$. However, dosimeters calibrated to the individual dose equivalent $H_p(10)$ or, under specific exposure conditions, the individual hand skin dose equivalent, $H_p(0.07)$, or the lens dose equivalent, $H_p(3)$ are most commonly used. Monitoring of individual exposure of employees is supplemented by active detectors (usually featuring a Geiger-Mueller tube) and radiation portal monitors measuring, e.g., body or clothing contamination. In addition, when the situation so requires, the measurements can be extended to include measurements of internal contamination (e.g., thyroid measurements, whole body counters, tests of secretions such as urine, faeces, blood or saliva), as well as retrospective dosimetry (e.g., based on cytogenetic blood testing methods).

For the purpose of developing radiation monitoring programmes for the First Polish Nuclear Power Plant, the experience of radiation monitoring of a nuclear facility area from the following three units in Poland can provide useful examples:

- the Nuclear Centre in Świerk near Warsaw,
- the National Radioactive Waste Repository (KSOP) in Rużan,
- the areas of former uranium ore mining and processing plants. In addition to local monitoring, there is also nationwide radiation monitoring carried out by the State Atomic Energy Agency [79].

2) **<u>Radiation monitoring of the Nuclear Power Plant surroundings</u>**

As mentioned in the previous point, in the case of radiation monitoring of the Nuclear Power Plant (off-site), two time phases can be distinguished: pre-operational monitoring, which usually begins about 2 years before the full commissioning of the power plant, and proper operational monitoring.

The objective of pre-operational monitoring [28] is to determine the "baseline" environmental radiation levels and activity concentrations before the commissioning of the nuclear power plant to determine its future radiological impacts on its surrounding area. According to the IAEA requirements [28], pre-operational monitoring should be initiated 2–3 years before the commencement of NPP operation (in practice, before the commencement of the first loading of nuclear fuel in the reactor core).

As the scope of monitoring is basically similar for both monitoring types, operational monitoring is described below.

As mentioned above, a draft Regulation of the Council of Ministers on the scope of the environmental radiation monitoring programme developed and implemented by organisational units classified under hazard category I or II [89] has been published. On the basis of the draft, it is possible to define the general scope and requirements for off-site radiation monitoring, although a detailed monitoring programme is developed and implemented in each case by the organisational unit concerned, in this case by the operator of the Nuclear Power Plant. The essential elements that the off-site monitoring programme should take into account are basically very similar to those for the on-site monitoring programme, <u>but with some significant changes of extent as indicated by the underlined text below:</u>

- automatic measuring stations: continuous measurement of gamma radiation dose rates together with parallel measurement of its spectrum (to determine radioactive isotopes in the air). In addition, the station should be able to measure meteorological conditions, i.e. the amount of precipitation, temperature, wind (force and direction), pressure and humidity. <u>The installation of at least 16 such stations around the Nuclear Power Plant is assumed</u> (it is worth noting at this point that about 40 similar stations (with different measurement capabilities) are currently in operation in Poland under the supervision of the National Atomic Energy Agency (PAA), collecting data on a 24/7 basis. It is the basic component of the national radiation monitoring system,

- active dosimeters: measurement once every two months of the gamma radiation dose rate by devices located at a minimum of 27 points around the Nuclear Power Plant, usually equipped with one real-time detector (e.g. a Geiger-Mueller tube),
- passive dosimeters: at least 37 points around the Nuclear Power Plant site where passive dosimeters are located – usually of the thermoluminescent (TLD), or optoluminescent (OSL) type. The advantage of such a solution is a much higher sensitivity than for Geiger-Mueller active dosimeters, while the disadvantage is the monthly or quarterly cycle of reading the dose counted from the entire measurement period. It is worth adding, however, that both systems, active and passive, complement each other well,
- atmospheric aerosol sampling point: two measuring devices (or sets of devices in the plant surroundings) using a filter and the deposition on the filter of atmospheric aerosols from pumped air, used to measure (with very high sensitivity) concentrations of selected radioactive isotopes, such as isotopes of strontium or plutonium, as well as total beta and alpha activity in the air,
- in-situ deposition and dry and wet radioactive fallout points: points for sampling and further analysis of selected radioactive isotopes that have settled naturally on horizontal surfaces, e.g. selected isotopes of caesium, iodine, cobalt, strontium and plutonium, as well as total beta and alpha activity (for radioactive fallout measurements),
- soil sampling points: as above, but this concerns the collection and isotopic analysis of soil samples taken from a minimum of 25 points in the NPP surroundings, for the monitoring of selected radioactive isotopes, such as caesium, strontium, plutonium, carbon, uranium, tritium and total alpha and beta activity,
- water intake points: through drinking water intakes (water pipes) and groundwater (piezometers) in the NPP surroundings. Isotopic measurement similar to soil samples, but complemented with dose rate, gamma and radon emitters, etc.,
- sampling points for other bioindicators: tests of the radioisotopic composition of samples of leafy vegetables, root vegetables, potatoes, fruits, cereals, grasses, milk, meat (poultry and game separately), eggs, mushrooms, mosses, lichens, needles, leaves, fish, crustaceans and molluscs, seaweed, bottom organisms, as well as products served in local canteens,
- sampling points for other material: bottom sediments, slurry (sewage sludge), sand from coastal beaches (for coastal locations) – for the analysis of isotopic composition.

It should be noted that radiation monitoring of the surroundings of the Nuclear Power Plant is specific to the distance from the border of the facility and the zone in which the sampling point is located. Therefore, the draft of the aforementioned regulation [89] contains detailed instructions regarding radiation monitoring divided into emergency planning zones (internal and external) and extended planning distance. However, due to the fact that the regulation has not yet entered into force, these details are not described here.

In addition to the in-depth analysis mentioned above, which involves taking various types of environmental samples, radiation monitoring of the environment of the nuclear power plant (off-site) also includes specific dosimetric measurements of selected individuals from the general population living in the vicinity of the power plant. To this end, the draft regulation [89] imposes mandatory measurement with a whole body counter of not less than three individuals from the population living in one of the emergency planning zones, at least once every two years. In particular, concentrations of radioactive isotopes that are gamma emitters are to be tested, as well as: Cs-137, Cs-134, I-131, Co-60, Zr-95, La-140, Ra-226, Ac-228 and K-40. A good example of the functioning of off-site radiation monitoring is the monitoring of the same three units in Poland specified in the context of on-site radiation monitoring.

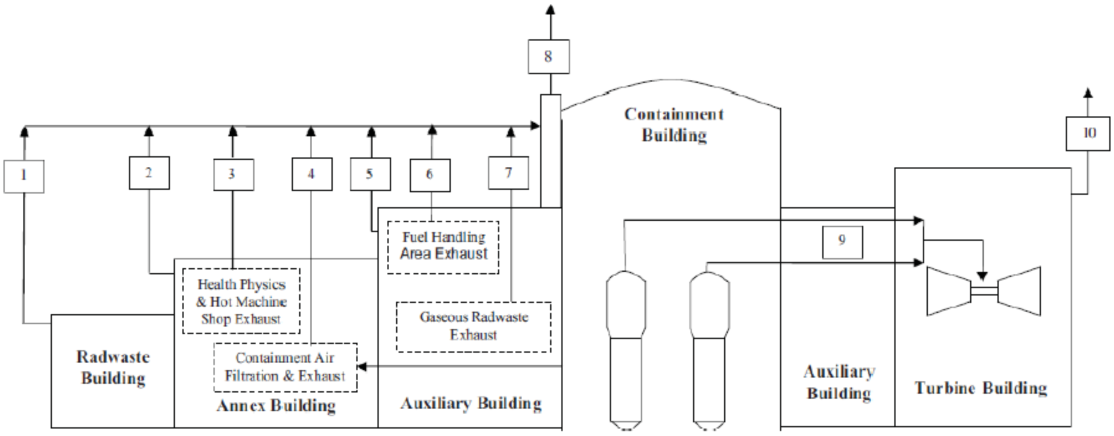
V.7.11. Waste management

V.7.11.2 Radioactive waste and spent fuel

Gaseous, liquid and solid radioactive waste is produced during the operation of a nuclear power plant. Radioactive waste management at the NPP site includes collection, sorting, processing, and interim storage, prior to shipment to a radioactive waste disposal facility. Continuous radiation monitoring is carried out at all these stages. Monitoring is also conducted for radioactive releases into the environment, both liquid and gaseous.

In the case of gaseous radioactive waste, “delay beds” will be used with radioactive noble gases that trap the gases for a period of time, permitting detailed monitoring and reducing the activity of radioactive substances emitted into the air due to the radioactive decay of short-lived radionuclides. These substances are then discharged into the environment in a controlled manner (via a ventilation stack). The entire emission process will be monitored to make sure that the limits defined in the permit issued by the President of PAA are not exceeded. In the case of liquid radioactive waste, monitoring tanks are used for storage of treated liquid waste containing radioactive substances (mainly tritium and carbon C-14) before its controlled release to the sea.

The figure below [Figure V.7- 3] shows schematically the sources of radioactive releases to the atmosphere, derived from the AP1000 unit systems, facilities, and rooms. The monitoring point in the stack is chosen to ensure that the sample is representative of the total volume of gas released.



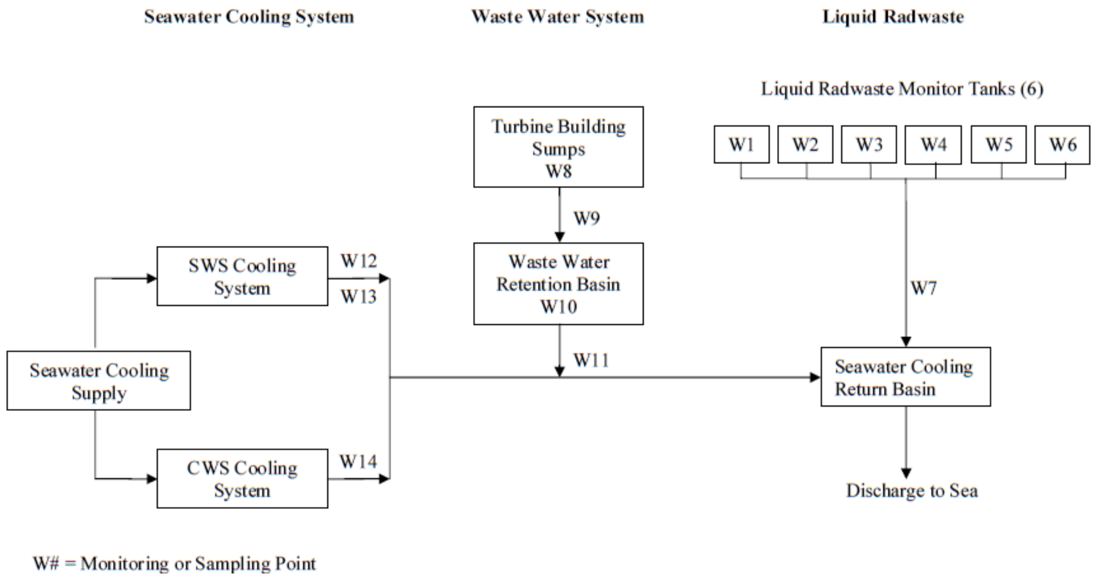
Radwaste building – budynek odpadów promieniotwórczych; Annex building – budynek zaplecza reaktora; Health Physics & Hot Machine Shop – ochrona przed promieniowaniem i dozymetria (pomieszczenia i wyposażenie) & warsztat "gorący" (do napraw skażonych urządzeń); Auxiliary building – budynek pomocniczy; Gaseous Radwaste – gazowe odpady promieniotwórcze; Fuel Handling Area – obszar operacji z paliwem jądrowym; Containment building – budynek obudowy bezpieczeństwa; Turbine building – budynek maszynowni; Exhaust – wylot.
1 - radwaste building exhaust, 2 - annex building exhaust, 3 - health physics & hot machine shop exhaust, 4 - containment air filtration exhaust, 5 - auxiliary building exhaust, 6 - fuel handling area exhaust, 7 - gaseous radwaste exhaust (WGS), 8 - ventilation stack, 9 - leaks from the main steam pipelines and from the primary to the secondary system of the steam generators (N-16 isotope), 10 - discharge from the turbine building.
Figure V.7- 3 Sources and monitoring points for radioactive air emissions
Source: [124], [77]

For liquid waste, on the other hand, the processed wastewater from each unit is collected in six monitoring tanks. The total capacity of the tanks allows for the storage of processed wastewater from approximately 42 days under normal operating conditions.

Discharge of processed wastewater from any tank into the environment is allowed only if the examination of the tank contents did not show any contraindications. If the requirements are not met, the contents of this tank can be pumped to a waste holding tank or sent directly to the start of the treatment process. The radiation detector is located on the common discharge line downstream of the monitoring tanks. This detector gives a signal to stop the discharge of wastewater if its activity exceeds a certain threshold.

Wastewater that meets the conditions for discharge into the environment will be discharged into the sea: in the case of an open cooling system (condensers and equipment of the "conventional island") - by the discharge of heated cooling water, and in the case of a closed cooling system - by discharge of blowdown and wastewater to the sea.

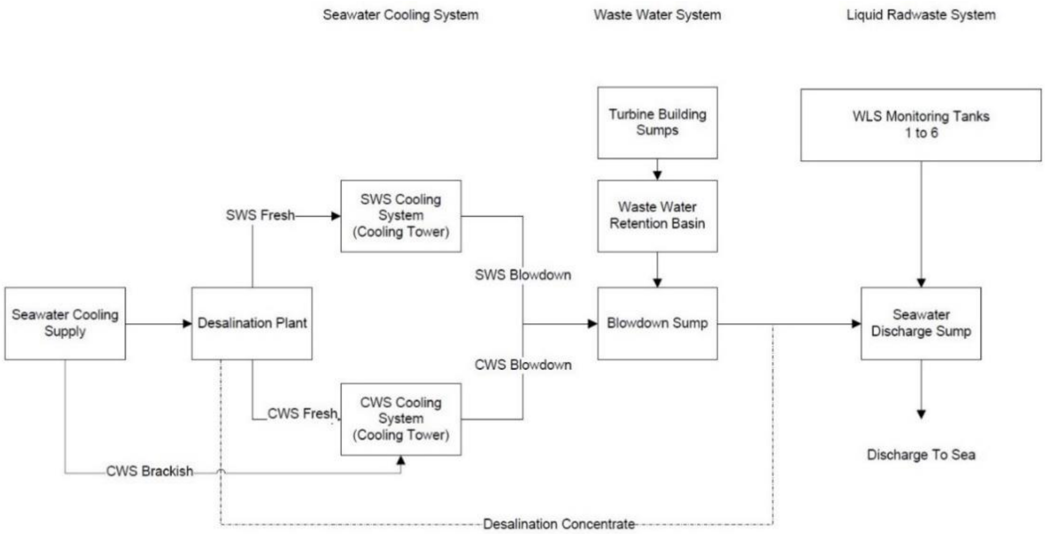
Figures [Figure V.7- 4] and [Figure V.7- 5] schematically show the effluent discharges and monitoring locations from the AP1000 unit's systems and process rooms for the open and closed cooling circuit sub-variants, respectively.



Seawater Cooling System – system chłodzenia wodą morską, Waste Water System – system wód odpadowych, Liquid Radwaste – ciekłe odpady promieniotwórcze, Turbine Building Sumps – studzienki w budynku maszynowni, Liquid Radwaste Monitor Tanks – zbiorniki monitorowania ciekłych odpadów promieniotwórczych, Seawater Cooling Supply – doprowadzenie morskiej wody chłodzącej, SWS Cooling System – system wody ruchowej, CWS Cooling System – system wody chłodzącej, Waste Water Retention Basin – basen retencyjny wód odpadowych, Seawater Cooling Return Basin – basen zrzutu morskiej wody chłodniczej, Discharge to Sea – zrzut do morza, W# – punkt monitoringu lub poboru próbek

Figure V.7- 4 Diagram of the discharge and monitoring points of wastewater from the systems and process rooms of a nuclear power unit with the AP 1000 reactor with an open cooling water system

Source: [124]



Sewater Cooling Supply – pobór chłodzącej wody morskiej; Desalination Plant – stacja odsalania; CWS Brackish – słonawa woda chłodząca; CWS Fresh – słodka woda chłodząca; SWS Fresh – słodka woda ruchowa; CWS Cooling System (Cooling Tower) – zamknięty system wody chłodzącej z chłodnią kominową; SWS Cooling System (Cooling Tower) – zamknięty system wody ruchowej z chłodnią kominową; CWS Blowdown – odsalanie obiegu chłodzenia; SWS Blowdown – odsalanie systemu wody ruchowej; Turbine Building Sumps – studzienki ściekowe w maszynowni; Waste Water Retention Basin – zbiornik retencyjny wód odpadowych; Blowdown Sump – studzienka odsalania; WLS Monitoring Tanks – zbiorniki kontrolne systemu ciekłych odpadów promieniotwórczych; Seawater Discharge Sump – studzienka zrzutu do morza.

Figure V.7- 5 Diagram of the discharge and monitoring points of wastewater from the systems and process rooms of the AP 1000 power unit with a closed cooling water system

Source: [124]

For solid waste, the radwaste building houses the process equipment for handling low-level radioactive waste. In this building, the sorting, conditioning and treatment of low-level waste of various types prior to processing and loading into transport and storage containers takes place. The radioactive waste building also contains the aforementioned six liquid waste monitoring tanks, which contain processed wastewater containing radioactive substances, ready for discharge to the environment.

In contrast, the handling of spent fuel (SF), assuming that it will not be reprocessed, is shown in the following diagram [Figure V.7- 6]. It is continuously subjected to radiation monitoring at every stage.

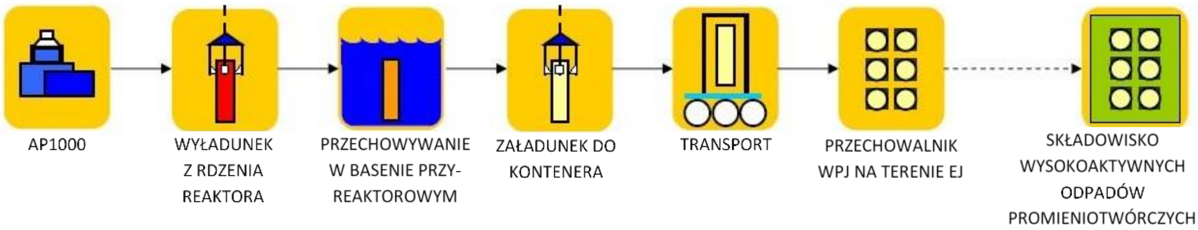


Figure V.7- 6 Spent fuel management

[Wyładunek z rdzenia reaktora – Fuel unloading from core, Przechowywanie w basenie przyreaktorowym – Storage in spent fuel pool, Załadunek do kontenera – Loading into container, Transport – Transport, Przechowalnik WSJ na terenie EJ – On-site spent fuel storage, Składowisko wysokoaktywnych odpadów promieniotwórczych – High-level waste repository]

Source: [132]

V.7.13. Human health and life

Scope of monitoring

Presented below is the scope of activities proposed to be used in relation to monitoring the impact of the Project on human health and life, including food products.

Monitoring is proposed to be conducted in the construction phase for:

- complaints submitted to the Investor by parties exposed as a result of possible nuisances related to excessive noise emission, air pollution, water quality, effluent discharge into the environment, access to the NPP site and the coastal areas and other possible nuisances affecting human health and life,
- concerns raised by the local community about the Project,
- public opinion on the method of collecting, reporting and providing information from environmental monitoring on the basis of an annual anonymous survey; this study will be an indicator of adjustment of the Project to the specificities and way of life of local communities,
- public opinion in areas of greatest concern and expectations on the basis of a semi-annual or annual anonymous survey,
- public opinion to identify the extent of local concerns about restrictions on access to land on the basis of an annual anonymous survey; this survey would be used to identify areas where improvements can be made in access to land located in alternative areas, and as an indicator of the adjustment of the Project adaptation to the specificities and way of life of local communities,
- transport infrastructure and changes to traffic management in the NPP area,
- all incidents and accidents in the NPP area,

- the NPP construction site, and then the operation area for unauthorised access to the Project Area,
- health and safety at work using a number of key performance indicators. The requirements of the OHS plan under the Project will apply to the entire workforce and subcontractor chain and will be translated into the native languages used by employees,
- the healthcare system and contagious morbidity.

Monitoring period

It is recommended that activities indicated in the construction phase should be continued in the operational phase for a period of 5 years from the end of the construction phase.

V.8 Indication of difficulties arising from deficiencies in knowledge, technology, or gaps in the contemporary knowledge, which were encountered while preparing the EIA Report

The difficulties encountered in preparing this EIA Report were related in particular to the uniqueness of the Project. So far, no project has been carried out in Poland involving the construction and operation of a nuclear power plant, so when preparing the EIA Report, it was not possible to draw on previous experience, developed practices and guidelines or judicial and administrative case-law, as is the case with other projects.

Due to the fact that the construction of a nuclear power plant is widely recognised as a project of the highest level of difficulty and complexity, and issues related to nuclear energy are highly specialised, the Applicant, when preparing the EIA Report, faced challenges unprecedented in the preparation of such studies in Poland. It should be emphasised that difficulties in this area appeared already at the stage of launching a comprehensive programme of siting and environmental surveys, and resulted on the one hand from its complexity and extensiveness (the substantive scope covered several research areas, and the spatial scope covered a vast land and marine area), and on the other hand from the lack of full knowledge of the design solutions adopted at that stage. As part of the implementation of the aforementioned survey programme, the Applicant had to process a significant amount of various data obtained during field surveys. Another problem was the diversity, incompleteness and diverse quality of existing historical data, i.e. data collected by other entities (not derived from in-house studies). Public administration institutions or other entities from which such data was obtained have different systems for data collection, processing and presentation. In addition to quality defects, the data obtained was often provided in different formats and came from different periods. For the purposes of the EIA Report, the Investor had to standardise and/or validate the data made available for later use (in particular, to conduct comparative analyses).

Considering the difficulties encountered in preparing this EIA Report, one cannot but address the complications caused by the Covid-19 pandemic triggered by the SARS-CoV-2 virus, which has so far been an unprecedented phenomenon on a global scale. The regulatory framework (constraints and restrictions) related to the Covid-19 pandemic have caused the emergence of gaps in data and great difficulties in data acquisition. The effects of the pandemic were also reflected in the data collected for issues under study covering the last two years (i.e. 2020 and 2021), which often deviate from the current trends. This, as well as the uncertainty as to the further course of the epidemic, was a significant obstacle in forecasting trends in a given area (in particular with regard to forecasting changes in socio-economic conditions). In addition, the process of preparing the EIA Report itself was also complicated. It was necessary to introduce significant changes (including remote work) in the organisation of the work of individual teams of authors of the EIA Report, which was particularly difficult with teams consisting of employees from different countries.

Presented below are identified difficulties, in particular those arising from technical deficiencies or gaps in current knowledge encountered in the process of the development of the EIA Report. It should be emphasised that the Contractor has made efforts to ensure that these difficulties do not have a significant impact on the quality of the EIA Report, using internationally developed solutions during its preparation and using the Technical Advisor’s extensive experience in the development of this type of documentation for nuclear facilities.

V.8.1. Difficulties arising from the state of knowledge on specific design solutions for the Project at the EIA Report stage

As mentioned above, during the preparation of the EIA Report, not all detailed design solutions for the implementation of the Project were known, which are to be specified only in the building permit design for the Nuclear Power Plant.

Accordingly, analyses of nuclear safety, radiation protection and nuclear technology were based on the generic design of the AP1000 nuclear power unit, in particular its European version (UK AP1000) submitted for assessment by the UK nuclear regulator as part of the General Design Assessment (GDA) procedure. In particular, the following documents submitted by the AP1000 technology provider to the UK nuclear regulator (ONR) were used: AP1000 Pre-Construction Safety Report, UK AP1000 Environment Report, and AP1000 European Design Control Document. It should be added that the construction design of the nuclear power plant will not reach the appropriate level of detail until the stage of drafting the Preliminary Safety Analysis Report.

This problem has also arisen with regard to the definition of detailed parameters of certain elements of the NPP infrastructure. For example, in the EIA Report, the use of cooling towers was proposed with the following dimensions: height – 202 m, diameter at base – about 169 m. These dimensions were indicated (based on calculations) by the Technical Advisor, but were not verified by the technology provider or by the EPC contractor. It is likely that at the stage of preparing the design documentation, the aforementioned cooling tower dimensions would have to be clarified.

The state of progress of the project at the EIA Report preparation stage also did not allow a detailed assessment of greenhouse gas (GHG) emissions into the air to be made. However, where possible, the estimation of GHG emissions at the current stage of the design process was carried out in a way that was adapted as much as possible to the specificities of the Project in Poland. The site variants of the Project are known, which is why it was possible to make realistic assumptions (worst-case scenario) regarding the distance of transport of building materials to the site. In addition, the GHG emission estimates could be adjusted on the basis of the benchmark for the Polish energy mix.

For the same reasons, it was not possible to fully assess the air emissions associated with the construction and operation process, but the practice of building energy facilities indicates that key sources and types of emissions have been identified and estimated.

Aspects related to waste management have also been analysed taking into account available information, documents and experience in this area; however, after the selection of the Plant Vendor and Construction Contractor, slight modifications and additions resulting from detailed information in this respect should be assumed, including construction methods and solutions that would form the basis for estimating the amount of waste generated, as well as methods of waste management. Therefore, the approach adopted was to assess the parameters and assumptions with the greatest potential impact. The EIA Report was based on the documents "AP1000 Environment Report" [133] and "AP1000 Integrated Waste Strategy" [131].

In addition, some difficulties were caused by the fact that detailed solutions regarding the NPP decommissioning phase are not known at the current stage of the Project. Bearing in mind that the NPP decommissioning process will begin in about 70 years at the earliest, it is difficult to specify how it will be carried out and the design solutions, technologies, and equipment to be used in the process. Keeping this in mind, it was reasonable in the case in question to set out general assumptions of the course of the NPP decommissioning phase, taking into account the regulations arising from national and international law, as well as the developed practices based on the experience of other countries in this area.

V.8.2. Difficulties arising from the availability and quality of historical data acquired

Another problem was the diversity, incompleteness and varied quality of data not sourced from in-house studies but obtained from other sources. Public administration institutions or other entities from which data was obtained have different systems for data collection, processing, and presentation. In addition to quality defects, the data obtained was often provided in different formats and came from different periods; moreover, sometimes it was inconsistent or incomplete.

Examples include difficulties encountered in work on spatial development issues, resulting primarily from the need to obtain data from many different sources of varied quality, as well as from the need for subsequent analysis, processing, and integration of the data into a single Geodatabase.

Also in forecasting the expected level of real estate prices, a number of technical difficulties were encountered, mainly related to the availability and quality of information, i.e. with a limited amount of information about real estate (e.g., lack of information on the state of repair, standard of buildings and structures, year of construction, etc.), incomplete, outdated and sometimes unreliable information on the development of plots, buildings and structures (lack of information about the latest, newly erected buildings, incorrectly recorded perimeters of existing buildings, resulting in incorrect building footprint area, lack of information or incorrect information on the number of building floors, incorrectly defined building use), contradictory information about a building / structure / site in different assigned data layers, lack or small number of transaction data for certain types of real estate (very rarely traded) and incomplete information on real estate which has been traded in the market (incomplete information in transaction data).

Seismic and tectonic surveys have also encountered difficulties related to the availability and quality of data. As regards understanding the geological structure and tectonics of the deep substrate, some interpretation problems resulted from the quality of some of the reflective seismic profiles (especially in the shallow zone), the lack of boreholes (especially in part of the marine region) and the deficiencies of geophysical borehole profiling and the uncertainty of determining the location of stratigraphic boundaries (for some boreholes). The above results from the fact that in addition to current seismic and borehole measurements (made as part of siting and environmental surveys) all available archival measurements were used to investigate tectonics in the Site Region. Archival data have been collected since the 1970s mainly for the purpose of gas and oil prospecting in Lower Palaeozoic formations. A different geological target and the execution methodology available in those years (despite the reprocessing of the data) often hindered the precise mapping of the Perm-Mesozoic and Cenozoic structural levels. However, the existing interpretation problems did not affect the credibility of the identified deep-rooted fault zones. Similar difficulties were identified regarding the earthquake catalogue for natural tremors. The number of earthquakes in the Macroregion is small, and in the seismogenic zones of Poland and the Kaliningrad Oblast it is very small. This is due to geological conditions. The Macroregion falls within the category of stable continental regions with low levels of seismic activity and long return periods of medium and large-sized earthquakes. The source earthquake catalogue used to assess seismic hazard includes data from the end of the thirteenth century. The first deficiency is the time for which there is no historical data on earthquakes. Deficiencies in the earthquake catalogue for natural tremors are also associated with regions where no chronicles were kept, i.e. in areas not inhabited in historical times. The distribution of seismic tremors identified in the Macroregion is largely determined by the level of civilisational development of individual areas (for historical shocks) and the distribution of seismological stations (for instrumentally recorded tremors). Another source of uncertainty is the lack of information about the depth of seismic tremors. At this point, it is also necessary to mention the problematic issues regarding the assessment of seismic hazard. The shortage of strong vibration data, as well as the shortage of appropriate soil vibration models, are common issues in assessing seismic hazard in stable continental regions. Therefore, as part of the update of the seismic hazard assessment, it is planned to drill a sufficiently deep borehole to confirm the lack of impact of the local geological structure on the value of the calculated seismic hazard.

The archaeological survey carried out in the years 2017–2019, as part of which an analysis of the archival query and field surveys were performed, also revealed numerous shortcomings of archival documentation, which are difficult or even impossible to supplement using non-invasive methods during surface surveys of archaeological sites and field reconnaissance of architectural monuments and culturally protected areas. During the query, a critical analysis of the references was carried out, as a result of which a number of inconsistencies were revealed, including location, legal protection status, identification numbers and dates of entry in the Register of Monuments relating to archaeological sites, architectural monuments, and culturally protected areas. Deficiencies were also visible in the Polish Archaeological Record (AZP, *Archeologiczne Zdjęcie Polski*) documentation. Sometimes, discrepancies were also found in the data obtained from the Voivodeship Monument Conservator and the National Institute of Cultural Heritage for immovable heritage assets included in the Register of Monuments. According to the new guidelines of the National Institute of Cultural Heritage, currently the survey results are presented as part of the digitised AZP grid, which differs from the intervals previously used in the Pomorskie Voivodeship (a shift of 100–400 m), hence in the area boundary strips archaeological sites could previously be assigned to another AZP area. With regard to architectural monuments, due to their large number and often the lack of exact address data for heritage assets included in the conservation records, the graphical appendices to Volumes III and IV [Chapter III.3.13], [Chapter IV.11] indicate their approximate location. The same was done with the location of archaeological sites. Where boundaries of the sites plotted on archaeological site cards were difficult to determine on the map, their approximate location was plotted. It should also be emphasised that during the inventory survey it was not possible to verify all known archaeological sites because during field reconnaissance areas inaccessible for investigation were found, which could not be entered. Archaeological surface surveys were not carried out on wet and partially or completely flooded land in the Site Area in both site variants, i.e. areas south of the Biebrowski Canal located between Osetnik and Kopalino, with a dense grid of drainage channels, the area of the Chełst basin between Ciekocin and Słajszewo and areas overgrown with dense dwarf pine located in the coastal strip east of Osetnik (Variant 1 – Lubiatowo - Kopalino site) and in the areas south-east of Lake Żarnowieckie, located at the mouth of the Piaśnica River along with a dense network of drainage channels in areas east of Opalin and west of Tyłów and areas located in the backwaters of the Czarna River, west of Lisewo (Variant 2 – Żarnowiec site). In addition, what turned out to be the basic gap in most archival studies was the lack or insufficient development of studies on construction techniques and methods (including testing of building materials, mortars, structure) for architectural monuments. The lack of regional statistical studies of brick material and analyses used to make mortars made it impossible in practice to verify the dating of finds using physical methods. Descriptions of conversions of architectural monuments was only exceptionally preceded by archaeological and architectural surveys, not to mention comprehensive and interdisciplinary research. These, in turn, are neither graphically nor descriptively reflected in the documentation collected.

The problem of availability and quality of data made available by public administration bodies and other entities also concerned issues related to socio-economic conditions, including the health of the population. The data made available was characterised by varying degrees of detail. Efforts were made to obtain data at the commune level, but in many cases data was available at the poviat or voivodeship level. Data on the local and regional identity of contemporary inhabitants of Pomerania was largely unavailable, hence it was difficult to make a comprehensive assessment in this respect. There are also discrepancies in the number of residents defined in the data provided by the BDL and obtained from communes. In addition, the level of detail of the data varies, which also affects the analytical possibilities of using data from the Local Data Bank (BDL) of Statistics Poland. Finally, the analyses were based on the BDL data. The information on internal and foreign migrations in the BDL also has significant limitations, since it contains information only about those individuals who have completed all the registration formalities related to the change of residence. Recorded migrations therefore reflect only part of the actual migrations, although they may provide insight into the general trends and demographic characteristics of migrants. There is also a lack of up-to-date, publicly available data on the morbidity of various diseases in individual communes, and patients often receive treatment outside their place of residence, or migrate. Therefore, most of the diseases analysed were assessed at the voivodeship level and some at the poviat level. The available epidemiological and monitoring data on asbestos concentrations is not detailed enough to estimate the level of exposure in individual poviats/communes, although it is sufficient to determine the presence of risk factors. Epidemiological data available worldwide on the impact of ionising radiation on human health is not conclusive, and research in this area is still ongoing. Much of the data shows the absence of a statistically significant increase in cancer risk in the low-dose area [135]. This means that the real impact of low doses of ionising radiation and low concentrations of radioactive substances on human health may be smaller than is commonly believed. One good example is the alleged increase in the morbidity of childhood leukaemia among the inhabitants of the vicinity of French nuclear power plants, which turned out to be due to either statistical errors (in data analysis) or caused by other factors (e.g., chemical contamination or genetic factors) [30]. There are no official statistics on people abusing or addicted to drugs in the Pomorskie Voivodeship. This is due to the lack of regional treatment programmes and the fact that treatment takes place outside the place of residence in order to allow patients to remain anonymous. Only Statistics Poland data from the period 2008–2018 on the total number of people treated in clinics for mental disorders caused by the use of psychoactive substances was available. There is no available data concerning: health impact of commonly used packaging (migration of contaminants from packaging to food, including endocrine active or genotoxic compounds), the possibility of government bodies testing the occurrence of contaminants in food not covered by national laws and regulations, and changing eating habits of the population of the Pomorskie Voivodeship, or detailed information on the content of contaminants in food available in the voivodeship/poviats. By the way, it should be noted that the draft (dated 30 July 2021) Regulation of the Council of Ministers on the scope of the environmental radiation monitoring programme developed and implemented by organisational units classified under hazard category I or II has not yet been adopted, and therefore it was impossible to specify a binding scope of such monitoring. Due to the lack of reference data, it is difficult to predict the scale of health effects caused by climate change, but taking into account the observed ongoing climate change, it can be assumed that negative health effects would intensify with the increasing incidence of extreme weather events.

It should be emphasised that the Covid-19 pandemic has some implications for the baseline data that has been collected and analysed. The presented trends in socio-economic conditions observed in the years 2010–2019 (2008–2017 for health data) do not include the effects of Covid-19, in particular demographic changes that occurred in 2020, changes in the labour market (the directions of these changes are difficult to predict), the increase in the unemployment rate or situation in the tourism industry. The analyses of the impact on human health and quality of life used data on the current situation for the period up to 2019, i.e. before the announcement of the COVID-19 pandemic by the World Health Organization (WHO) in March 2020. The above has an impact on the healthcare system in Poland and public health, and the changes resulting from the pandemic are not reflected in the available data. Despite the ongoing epidemic, the data obtained was considered sufficient to carry out a proper assessment of the impact of the Project on the health and life of the population.

V.8.3. Other difficulties or constraints of the methodologies or mathematical modelling used and the assumptions adopted

Any research method aimed at reflecting complex issues in a simplified way is fraught with errors resulting, among other things, from the need to standardise data and the accuracy of computational methods, as well as limitations of the applicability of mathematical modelling.

Thus, many forecasts used in the assessment of the impact of the Project on the natural elements in its marine component are based on a set of hydrographic models and dispersion modelling. Although these techniques are widely used, both as assessment tools and regulatory tools, the interpretation of modelling results requires a precautionary approach. The complexity of modelled systems inevitably involves a certain degree of simplification, and error is inherent in even the most sophisticated and carefully parameterised model. Models also depend on the accuracy of the inputs.

When it comes to impacts on air quality, the effects associated with the impact of local circulation systems (sea breeze) on the spread of pollution from high and low sources located in the coastal strip are poorly recognised. From the point of view of plant operation, knowledge of the physicochemical composition of atmospheric aerosols in the analysed area is limited. The current legal conditions do not require such analyses. It should also be emphasised that in the Site Regions the values of pollutant concentrations, both from measurements and modelled, are significantly lower than the relevant limits, which may cause modelling uncertainties to be high, but for the forecasting of concentrations it is not possible to determine uncertainties, as there are no calculation values against which the calculated concentrations could be benchmarked. In addition, given the fact that the environmental impact of the facility is analysed over a period spanning several decades ahead, i.e. it is a forecast with high degree of uncertainty, the pollutant concentration results obtained may carry some error.

The determination of the noise impact range is also fraught with error resulting from the accuracy of calculation methods, which is influenced by mathematical model simplifications and limitations. However, the key issue is the quality of input data, including, above all, the number of acoustic events, the time of noise emission and the sound power of individual devices. The types of equipment and sound power levels of individual noise sources used in the simulations were adopted on the basis of data furnished by the Plant Vendor, in-house data, literature data and standards. Since there was high uncertainty about the noise level associated with most of the data, i.e. the data entered into the noise model was a certain assumption, the analysis was carried out taking into account the "envelope of boundary conditions". A rational worst-case scenario was adopted for all assumptions to ensure that all reasonable options in terms of timeframe, arrangement and type of equipment are taken into account in the assessment. Due to the discontinuity of noise during construction works, it was not possible to present a thorough cumulative analysis in which two or more projects could increase the total noise level compared to the Project alone. Therefore, the cumulative impact of these projects was considered qualitatively. The qualitative approach was applied to planned or ongoing investments that are located in the vicinity of the Project or associated infrastructure, but are not related to the Project and are or will be implemented by third parties.

Difficulties were also encountered in developing assumptions and inputs for modelling the Project's impact on marine surface water. For example, when calculating the composition of discharged wastewater, the simplifying assumption was made of the entire amount of a chemical substance that is consumed (e.g., annual amount) would enter the environment (seawater). This means that the decomposition of the substance or its reaction with other compounds present in the water was not assumed. Such an approach leads to a deterioration in the quality of wastewater and to an increase in the impact zone after the substance enters the marine environment. With this in mind, it should be concluded that the actual impact will be smaller than that resulting from modelling.

On the other hand, in the case of the assessment of the Project's impact on inland surface water, all changes in biological indicators based on artificial neural network (ANN) modelling in terms of ecological status qualification for the considered water bodies (WBs) were estimated at less than 30% of the reference level. This is a range clearly below the uncertainty of the reference level of the ecological status assessment and the ecological potential determined on the basis of the error analysis performed by the GIOŚ in accordance with the methodology for estimating measurement uncertainty for the National Environmental Monitoring purposes, which amounts to 41% for the SWB code RW200017476925. Taking into account the general level of uncertainty which is a natural element of any assessment system based on measurements of physical quantities (41%) and the slight changes in indices for biological elements obtained from ANN modelling, it can be concluded that the level of uncertainty from ANN calculation is much lower than that reported by the regulatory body (GIOŚ), and therefore acceptable.

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Part 7

Appendix V.1.13-1

Description of models used for radiological impact analyses

Extract from Appendices to Volume V of the EIA Report

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świadomie o atomie
energia jądrowa w Polsce

Polskie Elektrownie Jądrowe sp. z o.o.

Table of Contents

1. RODOS system

The basic tool used in calculations was the RODOS system [1], [2], [3]. RODOS is a comprehensive decision support system that can be used to analyse accidental releases of radioactive substances into the atmosphere and into various aquatic environments. There are also appropriate interfaces to local and national radiation monitoring systems, meteorological measurements and forecasts and for its adaptation to local, regional and national conditions.

RODOS provides a comprehensive and continuously updated assessment of the exposure of the population to radiation following an emergency release of radioactive substances (or the threat of such release) into the atmosphere and/or aquatic environment. The dispersion and deposition of substances released into the atmosphere is predicted by means of a nested chain of models. These models consistently simulate the processes of dispersion and deposition of radionuclides over two different ranges, the local scale within an area of 160 km x 160 km, and the far range up to several thousand kilometres. Despite this, RODOS can also be used for predictive calculations of emissions of radioactive substances in NPP operational states. For mathematical models of dispersion and deposition of radioactive substances, it is irrelevant whether the radioactive substances originate from emergency releases or from emissions in NPP operational states.

Among the many models available, RODOS includes those models that best match the objectives and scopes of analysis. The local scale model chain (LSMC) includes the RODOS Meteorological Pre-Processor RMPP [4], the RIMPUFF contamination cloud dispersion model [5], [6], the ATSTEP extended contamination cloud dispersion model [2] and the DIPCOT Lagrangian model [7].

RMPP operates as an interface between meteorological data and atmospheric dispersion models (ADMs). For this purpose, the RMPP processes available meteorological data from the measurement network or from forecasts. The data may include wind speed and direction, air temperature, humidity, pressure, precipitation intensity, solar radiation, surface heat flux, cloud cover, mixing height, and atmospheric stability. The data is then processed, in order to provide more complete and systematic information, on a three-dimensional computational grid that can be used by any ADM implemented in the RODOS system.

RIMPUFF (Risø Mesoscale PUFF model) [5] is the basic model of atmospheric contamination transport and dispersion on a local scale. It is a simplified Lagrangian model designed to calculate the concentration of radionuclides and doses resulting from the dispersion of airborne substances. This model can use data from non-stationary and heterogeneous meteorological conditions, which are often required to be taken into account in connection with calculations used to estimate the effects of a short (emergency) release of volatile substances into the atmosphere. The model takes into account both homogeneous and heterogeneous terrain with moderate topography. A typical model grid covers an area of up to 50 km, but in the case of flat terrain it can be extended to mesoscale (150 km – 300 km). This model simulates changes in the time of emission of airborne substances by sequentially releasing a series of Gaussian plumes at a constant speed on a specific grid. The amount of airborne substances allocated to each release plume corresponds to the rate of release during the time between releases. The computational grid of the RIMPUFF model covers an area of 80x80 km with five cell size levels: 0.1x0.1 km, 0.2x0.2 km, 0.4x0.4 km, 0.8x0.8 km and 1.6x1.6 km, and around the power plant with a grid of 0.1x0.1 km it is a square of 2 km x 2 km (i.e. 400 computational cells). It was assumed that the releases occur at 17.8189 longitude and 54.8082 latitude for the Lubiatowo - Kopalino site, and for the Żarnowiec site at 18.0906 longitude and 54.7412 latitude.

DIPCOT (DIsPersion over COmplex Terrain) [7] is an atmospheric dispersion model that simulates the dispersion of air pollutants over a complex area. This is a plume of Lagrangian particles, in which the contamination mass is distributed to a certain number of fictitious plumes or particles that move in the computational domain according to the wind speed, to which a random component is added in order to take into account turbulent diffusion. Knowledge of the spatial and temporal distribution of particles allows the concentration of pollutants at specific places and times to be calculated. The DIPCOT model is used for areas with complex terrain features.

Atmospheric dispersion models used in the RODOS system have been validated on the basis of experimental data and other models in many publications, e.g. [8], [9].

ADM models provide information on radioactive concentrations in the air and on wet and dry deposition in the area under consideration (land and water), which is then used in the RODOS dose models.

In order to assess dose quantities, two main exposure pathways should be considered, i.e.:

(a) external exposure from the radioactive cloud and from contamination of the earth surface,

(b) internal exposure from inhalation of contaminated air and from the consumption of contaminated food and contaminated water.

Dose quantities significantly depend on the transport of radionuclides in the human environment. In the case of external exposure, dose quantities will be influenced by the amount of deposition (dry and wet – caused by rain) and the rate of isotope migration into the soil. In the case of internal exposure, the dose quantity will be affected by the complex pathways of the radionuclide passage in the food chains, i.e.:

deposition ⇒ feed ⇒ milk ⇒ human;

deposition ⇒ feed ⇒ animal ⇒ human;

deposition⇒plant⇒human; etc.

The transfer of radionuclides from the radioactive cloud to food, as well as the resulting radiation exposure, are modelled in the terrestrial food chain and in the FDMT dose module [10]. The activity concentration of soil, plants and other surfaces as input to FDMT is calculated in the DepoM deposition module, based on the results of the dispersion model. The transfer of radionuclides in food chains and other processes that determine radiation exposure depends on regional characteristics, such as climatological properties and agricultural use of land, and is therefore region-dependent. This means that many model parameters must be adapted before they can be applied to a specific area. To this end, RODOS can define so-called radioecological regions, i.e. areas with relatively uniform radiation conditions, for which the same set of model parameters can be applied. The selection of such regions is predominantly determined by the dominant regimes of agricultural production, growing seasons of plants, harvest time, ways of feeding domesticated animals, eating habits, etc.

The FDMT model has been implemented for Polish conditions by:

1. Acquisition of data for radioecological regions including:
   - Agricultural production data (obtained from Statistics Poland)
   - FDMT model parameters (obtained from Warsaw University of Life Sciences – SGGW, the Central Laboratory for Radiological Protection – CLOR and the Institute of Soil Science and Plant Cultivation in Puławy – IUNG)
   - Production data includes products of plant and animal origin and food and feed products, while the parameters of the FDMT model include the following data: soil and vegetation, plant growth rate, human diet and feed for farm animals.
2. Entering the parameters acquired for the respective radioecological regions into the RODOS system.

Production data has been entered for all poviats, which allows quantities to be determined for radioecological macroregions, because the boundaries of macroregions run according to the boundaries of poviats. [Figure V.1.13-1- 1] indicates radioecological macroregions for Poland including administrative division (voivodeships and poviats).

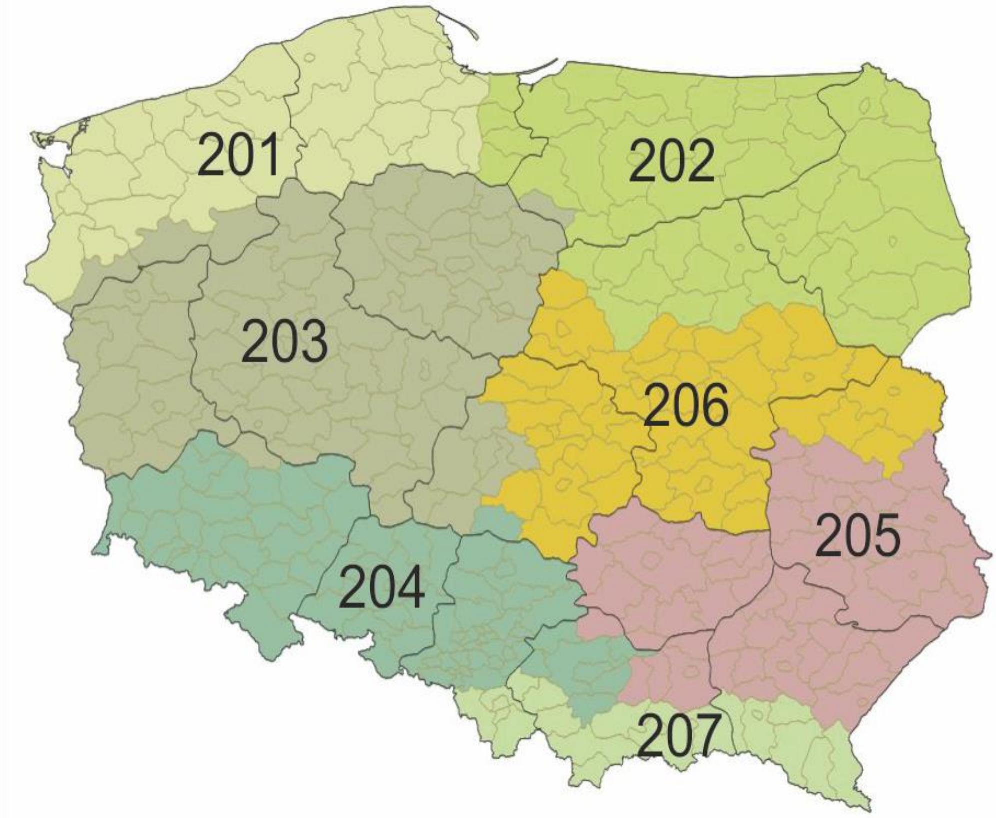


Figure V.1.13-1- 1 Map of Poland showing seven regions (the numbers indicate the number of the region in RODOS database).
Source: [11], [12]

It should also be added that the FDMT model, in addition to calculating doses taken by digestion, also determines the total effective doses from all external and external exposure pathways for different time periods and age groups. In addition, equivalent doses can be determined for a number of organs.

2. PC-CREAM package

The PC-CREAM package [13], [14] has been developed by the Health Protection Agency (HPA) in the United Kingdom and is widely recognised across the world as a reliable radiological assessment tool for collective and individual doses in the event of operational or accidental releases of radioactive substances into the environment. In particular, it is used for the estimation of impacts of operational releases from the MARIA reactor in Poland. This package allows a detailed quantitative study to be performed of the spread pathways of radioactive substances contributing to the total dose absorbed by the population. The input data for the calculations is data concerning the population, agricultural and weather conditions, together with the amount and content of the isotope in the specified material.

PC-CREAM consists of two main modules. The first one is a complex module consisting of several dedicated modules representing various physical phenomena related to the transport of radioactive isotopes in the atmosphere, water, their deposition on the ground surface and resuspension and circulation in food chains. The second main module of this code is the ACCESSOR module. It uses information from the specialised modules listed above, including population, agricultural and geographical data, to assess the doses received by the population in the considered region [15]. In addition, the program evaluates the contribution of each type of radiation to the total dose for the human body from various sources, for both short and long periods.

3. RETRACE model

RETRACE-1,2,3 [16] watershed models provide the speed of water, sediment and the inflow of radionuclides to the network of rivers, lakes and water bodies within a watershed based on information on the deposition of radionuclides and meteorological data (precipitation, temperature) transferred from the RODOS atmospheric module. Temporally dispersed data on the lateral water supply and radionuclide concentration is calculated in network nodes formed on graphs of river networks, shores of large lakes and reservoirs, or in separate nodes representing small lakes.

4. RIVTOX model

The RIVTOX river channel model [16], [17] performs simulations of contamination transport in networks of rivers and canals. The sources of contamination can be a direct release into the network or the contaminated runoff from a catchment. Waterflow, suspended sediment transport and contamination dynamics equation are averaged over a cross-section of rivers and canals. The “dispersion wave” model derived from the one-dimensional Saint-Venant equation is applied to describe water discharge. The dispersion and advection equation is used for calculations of suspended sediment transport in the river and canal network. The source term in this equation describes the rate of sedimentation and resuspension as a function of the difference between equilibrium concentration of suspended matter and its actual concentration at a specific flow level. The dynamics of the upper layer of the contaminated river channel is described by the equation for the erosion of the bottom layer. The numerical algorithm of the RIVTOX model is based on a calculation method for branched river networks successfully tested on the basis of the CHARIMA hydraulic code [18]. The conjugate gradient method is applied to the numerical solution of algebraic equations obtained by applying a technique known as “double sweep” to non-linear equations derived from the discretisation of Saint-Venant equations based on a four-step implicit scheme [19]. The finite difference method is used to solve the dispersion wave equation as well as the dispersion and advection equations that describe the transport of suspended sediments, contaminant solution sediments and contamination carried with suspended sediments. This method was also used for an equation describing contamination dynamics in the upper layer of bottom sediment.

The main results of the RIVTOX model in HDM hydrological models are cross-sectionally averaged concentrations of radioisotopes in water, suspended sediments and bottom depositions in the nodes of a river channel network. RIVTOX uses RETRACE model output to simulate river transport of radionuclides from a catchment or scenarios of direct release into water and can be used to simulate radionuclide transport from point sources. A special procedure is applied for interpolation of the RIVTOX model results onto the river channel network as the input grid of the waterborne dose of the FDMA module.

5. COASTOX model

The two-dimensional COASTOX model produces depth-averaged concentrations of radionuclides in the nodes of a rectangular grid, which includes a water body – parts of rivers near point sources of radionuclide releases, large shallow lakes, water reservoirs. The applied model includes sediment transport, dispersion-advection transport in water, the impact of contaminant and sediment, and the dynamics of bottom sediment. At the same time, the rate of sedimentation and resuspension is a function of the difference in the equilibrium concentration of suspension and its actual concentration, and it also depends on the flow capacity. The latter relationship is determined on the basis of semi-empirical relationships. Time-variable concentrations simulated by the COASTOX model can be interpolated to dose grid nodes or used after active cross-section integration as input files to the RIVTOX model if this model is used to model flow along a river. The new version of the COASTOX_UN model is a more computer-efficient model [20] of two-dimensional (depth-averaged) hydraulic flow, containing modules for the modelling of sedimentation and transport of radionuclides. The numerical solution is based on the discretisation of shallow water equations and the advection-diffusion equation using an unstructured grid (i.e. one with different elements) for the application of the finite volume method. The RIVTOX and COASTOX_UN models have been integrated in the RODOS-HDM system – boundary conditions are obtained from the RETRACE model [21].

The HDM models were validated based, among other things, on data for radioactive contamination of the Dnieper and the Clinch Rivers under the VAMP programme, coordinated by the IAEA and the EU [20]. These models were and still are used for analyses after the Fukushima accident [22], [23].

6. THREETOX model

THREETOX [24] is a three-dimensional model which generates radionuclide concentration files in 3-D grid nodes built for deep lakes and other stratified water bodies – estuaries, cooling basins of nuclear power plants, and marine coastal areas. This time-dependent 3-D system is used for interpolation to the FDMA dose calculation module grid, and can also be used for lake/reservoir runoff to the river to obtain a structural boundary condition for the RIVTOX model if measurement data is not available.

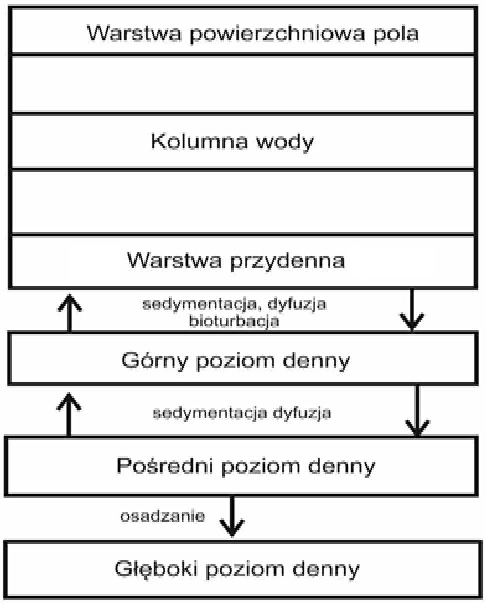
7. POSEIDON model

The POSEIDON-R model [25], [26], [27], [28] was developed to estimate the consequences of continuous or accidental releases of radioactive substances into seawater. It is based on a three-dimensional compartment (box) model, which allows calculations to be made at a large spatial and temporal scale. The POSEIDON-R model uses information on direct deposition to the sea and on the runoff of contaminated inland surface water into the sea as input data. The dispersion of radioactive substances takes place through adjacent boxes and entire vertical water columns, taking into account the following dispersion mechanisms:

- Horizontal and vertical water exchanges between boxes;
- Adsorption on suspended sediments;
- Depletion of activity in suspended materials in equilibrium with the water phase activity;
- Exchange of radionuclides between water columns and the bottom through the molecular diffusion and bioturbation phenomena.

A more detailed representation of water columns and their sediment layers, as well as their interaction with neighbouring volumes, is shown in [Figure V.1.13-1- 2]. The boxes describing the water column containing suspended matter are subdivided into several layers. The radionuclide concentration for each water column layer is governed by a set of differential equations. These equations consider temporal variations in the nuclide concentration, the exchange with adjacent boxes due to advection, deposition and turbulent diffusion processes. In addition, the transfer of source activity from suspended matter to bottom sediment is considered. Temporal variations in the three sediment layers located under the water column are described in other sets of equations. These equations consider the transfer of isotopes between the water column and sediment and radioactive decay. The transfer of isotopes from the upper sediment layers to the water column is described by diffusion in water and by bioturbation. Radioactive concentration in the upper sediment layer migrates downwards by diffusion and penetration at the same rate as that at which particles settle from the overlying water. The upward transfer of radioactive isotopes from the mean sediment level to the higher sediment layer occurs only by diffusion. Penetration causes an effective loss of radioactive isotope concentrations from the intermediate to the deep sediment layers, from which no further upward migration occurs.

The transfer of radionuclides to marine organisms is described using the BURN dynamic absorption model BURN [22], [25]. This model takes into account the structure of the food web and the trophic level of organisms. BURN is basically a model of absorption into tissues and it considers the community of marine organisms. This model is a combination of salinity dependence factors for several radionuclides, which allows a good description of the absorption of nuclides from seawater into tissues. BURN is a generic model, essentially suitable for all radionuclides. However, most experimental studies have focused on a limited number of radionuclides - this model has been validated for nuclides such as caesium and strontium.



Warstwa powierzchniowa pola	Surface box
Kolumna wody	Water column
Warstwa przydenna	Near bottom box
sedymentacja, dyfuzja bioturbacja	settling down, diffusion, bioturbation
Górny poziom denny	Upper bottom layer
sedymentacja dyfuzja	settling down, diffusion
Pośredni poziom denny	Intermediate bottom layer
osadzanie	deposition
Głęboki poziom denny	Deep bottom layer

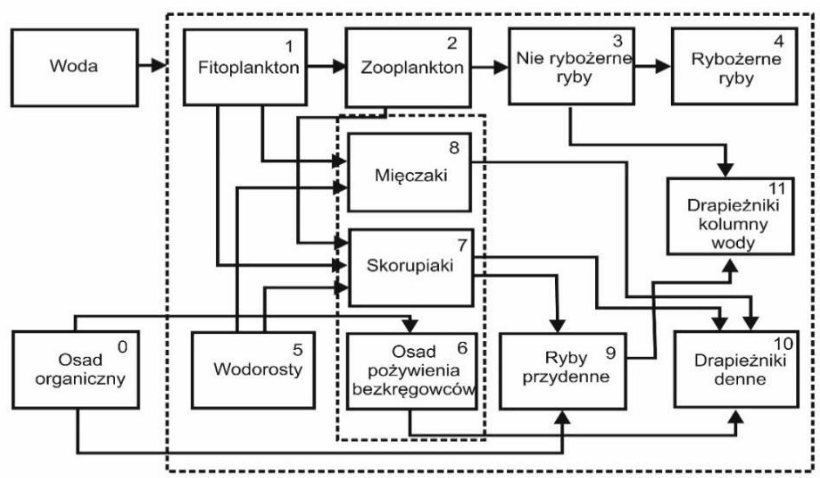
Figure V.1.13-1- 2 Structure of the POSEIDON-R generic compartment model

Source: [27]

For the purposes of the RODOS system, an extended dynamic model of the food web has been implemented. In this model, the number of input parameters is limited by grouping: (a) marine organisms into classes based on their trophic level and species type, and (b) radionuclides into classes associated with fish with dominant tissue in which there is an accumulation of a specific radionuclide. In addition, standard sets of input parameters were used to avoid the need to collect specific local parameters for a large number of different species and for each possible radionuclide, which is usually required in complex ecological models. The pattern of radionuclide transmission through the marine food web is shown in [Figure V.1.13-1- 3]. In the pelagic zone and in the bottom zone there are different food chains. Pelagic organisms are grouped into classes from primary producers (phytoplankton) and consumers: zooplankton and fish (predatory fish and non-predatory fish). All organisms also absorb radionuclides directly from the water. This food web was implemented into POSEIDON-R compartment model. The addition of the bottom food web contains different pathways for radionuclides:

1. By contaminating water as a pelagic food web,
2. Through the vertical flux of detritus and zooplankton faeces,
3. Through contaminated bottom sediments.

The bottom food chain contains the transfer from bottom sediment to the sediment of invertebrate food and to demersal fish and bottom predators. The components of this system are crustaceans (feeding on e.g. detritus, dead particulate organic matter), molluscs (filtering food) and coastal predators in the complete water column of shallow coastal waters. Together with the food web, these organisms take radionuclides directly from water.



Woda	Water
Fitoplankton	Phytoplankton
Zooplankton	Zooplankton
Nie rybożerne ryby	Non-piscivorous fish
Rybożerne ryby	Piscivorous fish
Mięczaki	Molluscs
Skorupiaki	Crustaceans
Drapieżniki kolumny wody	Water column predators
Osad organiczny	Organic deposits
Wodorosty	Seaweed
Osad pożywienia bezkręgowców	Invertebrates’ food sediment
Ryby przydenne	Demersal fish
Drapieżniki denne	Bottom predators

Figure V.1.13-1- 3 Diagram for radionuclide transfer by marine organisms

Source: [27]

8. FDMA model

FDMA (Food and Dose Modules Aquatic) is a model for simulating the transfer of radioactive substances in the aquatic food chain caused by water contamination (used for drinking, feeding animals or in the cropland irrigation system) in order to estimate the doses for the population resulting from the consumption of water, agricultural products and fish [29]. The input data to the FDMA module in the RODOS system is the output data from the HDM module, characterising the contamination of water bodies. Thus, the main data are therefore the concentrations of radionuclides in surface water as a function of time. The FDMA module, in turn, makes it possible to estimate activity in various types of food products and animal feed and, consequently, to assess the doses for the population from the aquatic food chain, contaminated water and the consumption of contaminated fish, thus providing input to the basic FDMT dose model of the RODOS system.

Part of the values of the model parameters refers to the physical and biological properties of the processes (dose coefficients, transfer rates) and they do not depend on the region under consideration. The others depend on the data characterising the region concerned – in the case of this implementation, they have been taken from data on radioecological macroregions for Poland. The most important of these are:

- irrigation data,
- harvest periods and yields,
- farm animal feed,
- periods of storage and processing of food products,
- human consumption rates,
- size of the population in the area under consideration.

9. Methodology for using the HDM model chain for dose calculation

The first step necessary to estimate doses from surface and groundwater contamination coming from air contamination is to use the results of a simulation of the LSMC model of atmospheric contamination transport and dispersion. In particular, these are values that are actually intermediate in the LSMC calculations, such as soil contamination. For this purpose, it is necessary to use the option of contamination of land and water bodies. This applies to both operational emissions and accidental releases. The results of the LSMC model are also used to select those meteorological sequences that contribute to the greatest contamination of either coastal waters or inland waters. As for the choice of meteorological sequences, it is based on data sets from reference years. The method of selecting meteorological sequences consisted of two steps:

- Using meteorological data sets from three reference years and data preselection to eliminate those meteorological sequences that do not cause significant contamination of surface water and groundwater.
- Selection of those sequences that result in the highest depositions in the area under consideration.

In the case of liquid operational emissions, the procedure is simpler, as the POSEIDON model alone is sufficient.

The next step is to implement the HDM model chain. The general model adaptation scheme consists of the following steps:

1. Processing of data from hydrographic networks, the coastal zone and hydrological and meteorological stations of the survey area (i.e. inflows from the Piaśnica and Bychowska Struga rivers to Lake Żarnowieckie and the path along Lake Żarnowieckie and the Piaśnica River to the Baltic Sea (RETRACE-RIVTOX and COASTOX for Lake Żarnowieckie) and marine input data for the POSEIDON model. It should be added here that the LSMC simulation area is an area of about 80x80 km, and thus includes the considered catchment area around the potential NPP sites.
2. Calibration of hydrological parameters / hydraulic models of rivers and lakes (RIVTOX, COASTOX) based on existing data from hydrological observations and analogous calibration of water exchange parameters between areas for the POSEIDON model.
3. Testing and necessary modifications of the software interface of HDM models.
4. Adapting the interface to the output from HDM models to present the results obtained from HDM modelling.

In order to implement the RETRACE and RIVTOX models for calculations in the RODOS environment, it was necessary to perform the following steps:

1. Data preparation and configuration of the RETRACE flow model.
2. Preparing data for the RIVTOX model, which will simulate the transport of radionuclides in surface waters in accident conditions, while the results of the RIVTOX model provide input to the FDMA dose model.

The first item includes the following elements:

- On the basis of the data obtained, a river network geometry model was prepared. The grid representing the river model is constructed so that the modelled rivers are divided into sets of segments, nodes and connections. A GIS model was also prepared in the Shape file format. The file contains details of the river network geometry – it is used by the RETRACE model, which is used to determine the volume of flows from the catchment area of the considered river network. The same file is also used for graphical presentation of the results of the simulations and becomes part of the RODOS system interface.
- River cross-section data was prepared and assigned to points of the model domain.

The second item includes:

- Preparation of boundary and initial conditions in a specific format used in the RIVTOX model. The results of the hydraulic model are compared with the data from observations in order to match the model parameters.
- The use of simulation data from the atmospheric dispersion model – this part is provided by the interfaces of the RODOS system.

Following the above steps, the adjusted model is implemented into the RODOS system environment.

[Figure V.1.13-1- 4] shows an implemented GIS-based model of the main river network including Lake Żarnowieckie tributaries (the Bychowska Struga and Piaśnica rivers), the lake itself and the outflow from the lake, i.e. Piaśnica estuary into the sea.

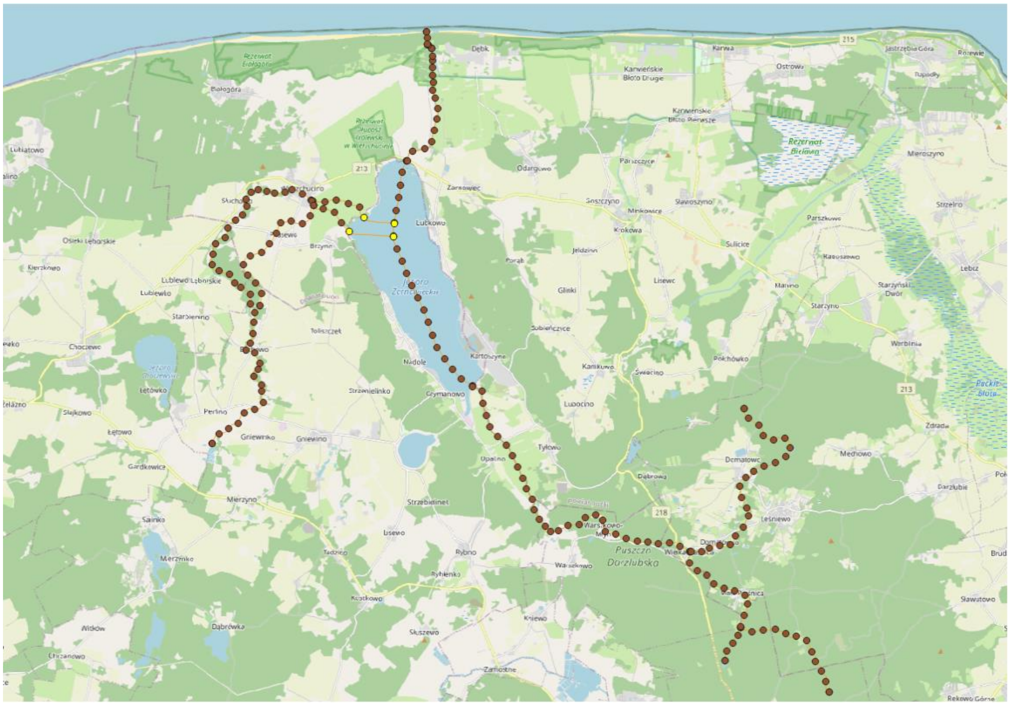


Figure V.1.13-1- 4 GIS-based river network model
Source: [11], [12]

At each point of this network, appropriate geometric values were assigned, i.e. cross-sections and bathymetry of Lake Żarnowieckie, using data from the spatial model and from the water gauge stations Za1-Za5.

As with the RIVTOX model, the two-dimensional COASTOX model was adjusted to the area of Lake Żarnowieckie on the basis of bathymetric data. The entire grid consists of 38,839 cells with a typical size of 50 m. Based on the test case, it was found that the propagation speed is low due to the low water velocity in the lake (of the order of 0.00001–0.001 m/s).

The POSEIDON-R [27] model is used to simulate radionuclide transfer in water and bottom sedimentation. The transfer of radionuclides is determined by sea currents; therefore, the proper flow values between the considered volumes are significant for the implementation process. Flow values are determined on the basis of three-dimensional velocity boxes. The POSEIDON implementation process consists of the following steps:

- validation of the circulation model by comparing the calculated water velocities with the measurements;
- creation of a new high-resolution computational grid, including the determination of the flow rates between individual volumes based on data from the circulation model;
- integration of the computational grid with interfaces of the RODOS system;
- performing test simulations.

The first step of implementation was the use of the NEMO-Nordic* circulation model for a 10-year period (2009–2018). The resolution of the model is approximately 3.7 km, which means that it was necessary to fine-tune the parameters of the model in order to achieve better compatibility in the case of nearshore flows (this basically concerns currents because tidal phenomena are practically non-existent in the Baltic Sea). For this purpose, measurement data was used, acquired from buoys located fairly close to the shore. A typical distribution of currents is shown in [Figure V.1.13-1- 5].

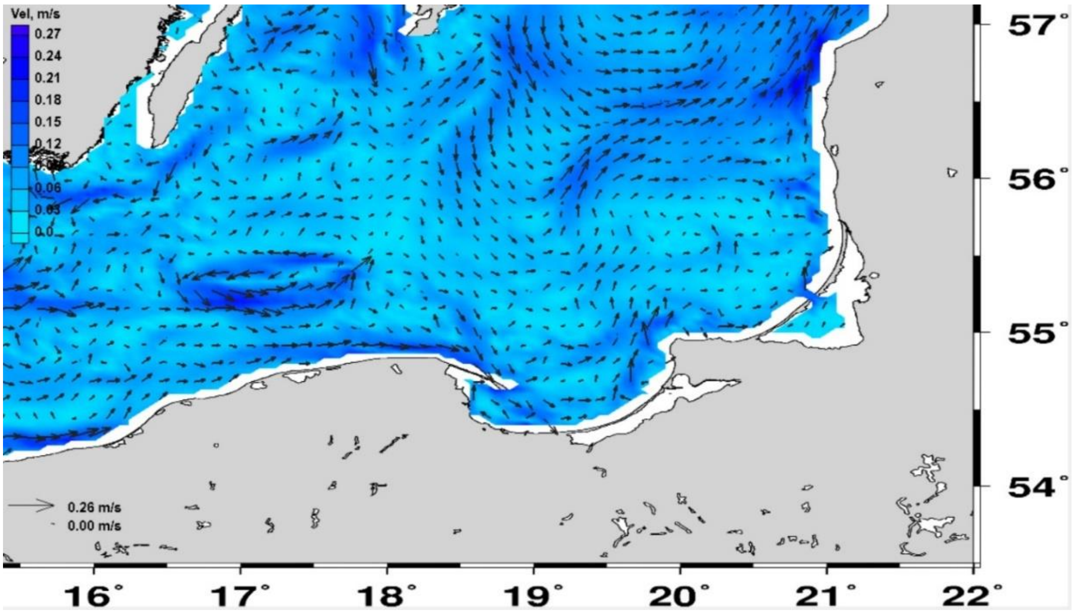


Figure V.1.13-1- 5 Characteristic distribution of surface currents (1 May 2018 data) based on the NEMO-Nordic model.

Source: [11], [12]

The resolution of the NEMO-Nordic model is 1/30 of a degree of latitude and 1/18 of a degree of longitude, which corresponds to about 3.7 km in both directions. Based on this resolution, in the second step of implementation, a computational grid of the POSEIDON-R model was created with a minimum volume area with a grid cell of 11x11 km (which corresponds to approximately 3x3 computational nodes in NEMO-Nordic model grid cell). A grid of this size was formed along the coast, with larger cells of the grid located at a further distance from the shore.

The volumes and average depths in each grid cell were determined on the basis of bathymetric data. For greater depths of grids cells, they were vertically divided into a surface layer and a bottom layer to better describe the stratification of concentrations.

In the next step, this grid was implemented as a computational grid in the RODOS system.

In addition to contamination due to liquid operational emissions, marine contamination can also occur through atmospheric emissions and deposition (on land and water). It is important in this situation to determine special grid cells (coastal box) at the very seashore in order to obtain dose values in the coastal area. In the NEMO-Nordic model, the size of such a cell is determined by the following parameters: volume of 0.132 km^3, depth of 10 m, water exchange rate with an outer (more distant from the shore) grid cell of 7.5 km^3 / year. The remaining parameters are the same as for the outer cell.

10. MODFLOW model

One of the most popular groundwater dynamics models is MODFLOW [30]. Due to an extensive set of additional packages and programs that can be used during simulation, it offers a very wide range of applications. Additional off-line models should be used to simulate pollutant concentrations, as MODFLOW itself is used to model groundwater dynamics rather than pollution transport. The main assumptions of the MODFLOW model were to

accessed online at http://marine.copernicus.eu/services-portfolio/access-to-products/

simulate groundwater flows in two or three spatial dimensions. MODFLOW, being developed by the U.S. Geological Survey (USGS) since 1990, is now one of the most widely used models designed to simulate groundwater flow and forms the basis for the development of various extensions and application models. The structure of the model is modular. MODFLOW is a water flow model described by a differential equation (parabolic type) in which the piezometric height is unknown, and the processes are parameterised by filtration coefficients. The user of the model must specify the size of the source, the initial piezometric head and the boundary conditions. As it is not necessary to use the entire set of equations with which MODFLOW is equipped, it has been divided into packages. The system user chooses which of them they will need for a specific task MT3DMS (Modular Three-Dimensional Multispecies Transport Model) is a supplement to MODFLOW that allows the simulation of pollutant flow in groundwater. It is a general-purpose dispersion model that requires data from a groundwater dynamics model. The MT3DMS [31]model is the successor to the older MT3D model for the transport of pollutants dissolved in groundwater.

As part of ongoing studies [32], [33], a hydrogeological and groundwater model has been built using the Groundwater Vistas package. It is basically a graphical design system for MODFLOW or other similar models such as MT3D, which facilitates the creation of MODFLOW projects and computational models. The results of simulations carried out using these models are presented using contour sketches, contour fills, velocity vectors, and detailed mass balance analyses. For modelling groundwater contamination, the developed MODFLOW model was used to determine flow characteristics in soil, which is the basis for the model of contamination transport and dispersion in porous layers.

At the same time, the simplified PC-CREAM 08 [14] code, which is considered as a reliable tool for radiation assessments of collective and individual doses in the case of operational emissions or accidental releases of radionuclides into the environment, was used for the initial calculations. It allows for the performance of a detailed quantitative study of the dispersion pathways of radionuclides contributing to the total dose absorbed by the population. The input data for the calculations is data on the population, agricultural and weather conditions, together with the amount and content of the isotope in the contaminated material.

One of the models of the PC-CREAM08 package is GRANIS – a module for simulating the migration of radionuclides in soil, which enables the determination of radioactive concentrations in soil (generally in porous layer) and dose assessment. Usually, the first step is to determine the contribution to the absorbed doses arising from different layers of soil. This takes into account soil properties and the energy ranges emitted by radionuclides. The GRANIS model was validated with both analytical methods and other codes (including MODFLOW) – it was observed that differences across the energy spectrum from 0.1 to 4 MeV are a factor less than 2 [34]. Estimates of radionuclide concentrations in soil are quite satisfactory [35].

The GRANIS model was used primarily to assess the magnitude of radioactive concentrations in the ground based on deposition in the area under consideration. It should be added here that the PC-CREAM package provides more conservative results when compared to MODFLOW.

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[33] Dodatek nr 1 do dokumentacji hydrogeologicznej określającej warunki hydrogeologiczne w związku z zamierzonym wykonywaniem przedsięwzięcia mogącego negatywnie oddziaływać na wody podziemne, w tym powodować ich zanieczyszczenie, tj. Elektrowni Jądrowej – wariant lokalizacji "Żarnowiec" [Addendum No. 1 to Hydrological documentation setting out hydrological conditions in connection with the intended execution of a project having a potential negative impact on groundwater, including its contamination, i.e. the Nuclear Power Plant – "Żarnowiec" site variant], BLS_GEO_BGEO2_DG_10003_AA_PL

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List of Figures

Part 7

Appendix V.1.16-1

Description of models used for radiological impact analyses in accident conditions

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Extract from Appendices to Volume V of the EIA Report

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Table of Contents

1. Modelling of the dispersion of radioactive substances and determination of doses at a distance of up to 30 km from the NPP

1.1. Modelling of the dispersion of radioactive substances released into the atmosphere and determination of doses associated with those releases

A description of the models used is provided in [Chapter V.1.13], but only the RODOS system was used to estimate the radiological impact of the NPP on the environment in accident conditions at a distance of up to 30 km, in particular the RIMPUFF atmospheric contamination transport and dispersion model and the FDMT dose model, taking into account the existing radioecological macroregions in Poland. The RMPP pre-processor was used to process meteorological data, which is part of the LSMC model chain of the RODOS system. The method of selecting meteorological sequences is also described in Volume V [Chapter V.1.13], while:

– 115 selected sequences from the reference years 2005, 2010 and 2012 (plus two special ones from 1995) were used to determine the restricted use area (RUA) according to three different criteria and 44 sequences from the 24-month monitoring period, i.e. a total of 159 sequences [Appendix V.1.13-2];

– 146 sequences from 2010 (reference year in terms of exposure and deposition) were used to determine the emergency planning zones and distances of extended planning and planning of consumption and control of goods, assuming alternating releases during the day and night (every other day, i.e. actually every two and a half days) and 44 sequences of the same type from the 24-month monitoring period, which resulted in a total of 190 sequences.

The basic assumptions for the calculation of dose values for the individual criteria are as follows:

- Doses were set for adults and infants (as a special exposure group – regulations do not specify for which population group doses should be calculated, so members of the public should be assumed, as for limit doses).
- The calculations were made to take into account all releases from their beginning and throughout their duration – for example, for monthly releases, the simulations covered a period of 780 hours. Doses for longer periods (e.g. annual, biannual, lifetime) are determined by the appropriate modules of the RODOS system.
- Ingestion doses were determined assuming the consumption of products from the analysed area using radioecological data for the specific region of Poland, collected in the RODOS system database.
- The dose for a foetus was calculated according to the British document [1] “HSE Doses to the Embryo/Foetus and Neonate from Intakes of Radionuclides by the Mother”.
- The RODOS system does not allow direct determination of a 30-day dose after 2 years. This dose is estimated as follows: the difference between the 2-year and 1-year doses is counted, thus obtaining the dose in the second year, then it is divided by 12, which can be interpreted as an estimate of the dose from the 24th month (instead of the 25th month). The dose estimated this way would certainly be higher than the actual one because the function of the cumulative dose over time (after one year from release) is concave (the dose decreases quasi-exponentially).

The doses from all exposure pathways can be estimated with by means of the FDMT model for various periods, and for both adults and children. In the case of thyroid, the standard is to determine the equivalent doses. As regulations refer to absorbed doses, effective doses were converted into absorbed doses using dose conversion coefficients from the ICRP-116 publication “Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures” (Annexes A and B including data corrected in Corrigenda for Publication ICRP 116).

1.2. Modelling of the transport of radioactive substances to surface water bodies and determination of doses associated with their contamination

In the case of the AP1000 reactor, the direct release of radioactive substances into surface water is practically excluded, both in the case of a bounding design basis accident and a severe accident considered in the extended design conditions, which is a severe accident considered in DEC and representative for emergency planning.

Thus, surface water can only be contaminated from the deposition on water surface of radioactive substances released into the air, wash-down of radioactive substances deposited on the land surface and (also indirectly) from contaminated groundwater (as a result of deposition of contamination on the land surface and their transport in the ground to groundwater). Thus, phenomena are modelled which involve the deposition of radioactive contamination from the air to the land surface and surface water and the transport of contamination deposited on the land surface to groundwater and then in groundwater to surface waters.

The water chain models are described in Volume V [Chapter V.1.13]. Specific information on modelling the transport of radionuclides and doses from the "water path" (including surface waters and groundwater) in accident conditions is provided below.

The method of applying the HDM model chain generally includes:

1. The implementation and modelling of radionuclide transfer in the water path (tributaries: Piaśnica and Bychowska Struga) to Lake Żarnowieckie, the waterway across Lake Żarnowieckie and the Piaśnica River to the Baltic Sea (RETRACE- RIVTOX and COASTOX for Lake Żarnowieckie). The transport of radionuclides in the ground, groundwater contamination and the transfer of radionuclides to surface water is simulated using a groundwater model. This involves the following contamination dispersion pathways: deposition of contamination on the land surface, its transport to surface waters (by leaching), then spreading in the ground and groundwater (by filtration and other phenomena), and finally contamination of surface water from contaminated groundwater.
2. Modelling of doses through a water path based on scenarios calculated using RIVTOX-COASTOX and FDMA models.
3. Modelling of radionuclide transfer in the marine environment and respective doses using the POSEIDON model.

The simulation results include:

- times of contamination transmission along the main water path,
- activity in water at selected points of the inland water network and in the sea,
- doses resulting from contamination of the aquatic environment.

It should be taken into account that, unlike small rivers, in the case of large water bodies, such as Lake Żarnowieckie, deposition (dry and wet) on the surface of waters and land, can significantly affect the dose quantity for the population. The need to take deposition into account means that modelling with the entire model chain in the RODOS system is essential. Input data on land contamination is provided by the LSMC model. In turn, the transport of radionuclides in the ground to groundwater and subsequent contamination of surface waters is essentially done using a hydrogeological model.

Two methods were developed and tested to implement the HDM model chain:

1) The use of a two-dimensional COASTOX model to interpolate the deposition from the LSMC transport and dispersion model directly to the computational grid and to simulate transport processes in Lake Żarnowieckie.
2) Modification of the RETRACE model to take into account the runoff of contamination from surface water.

The COASTOX model requires the provision of boundary conditions: hydraulic and radiological in the form of time series. The RIVTOX model was used to determine the flow rates and concentrations of radionuclides at the boundaries of the COASTOX model computational domain. Since the estimated transport time along the lake can be quite long (several months), it should be noted that radionuclides with a long half-life, such as isotopes of caesium and strontium would play a key role (while e.g. iodine only to a limited extent). As a certain simplification in the model, it is assumed that deposition occurs during a short time, which allows a simulation to be performed with the COASTOX model after completion of simulation with the LSMC model. This assumption is justified, on the one hand, by the low speed of transport of radionuclides in the lake and, on the other hand, it is actually conservative (the entire deposition is not distributed over time), so it does not carry the risk of underestimating the effects.

Finally, the results of the COASTOX model were used as boundary conditions for the RIVTOX model to estimate the propagation of radioactive concentrations along the water path to the sea in the Piaśnica River.

It should be noted that observational data for water flows and levels indicates a fairly constant inflow to Lake Żarnowieckie not exceeding 2 m3/s (measurement data from the period 2017–2018). In this situation, transport would be expected to be dominated by diffusion processes throughout the year. However, the situation could change in the event of high water levels in the spring and the occurrence of flooding – additional data would be necessary for such estimates. It should be added, nevertheless, that for these changes to be significant, the volume of the flow would have to increase by at least an order of magnitude. In addition, a lower flow rate results in a longer period of radionuclide retention in the reservoir, which is a conservative approach from the point of view of dose estimation.

The next step is to use the results of the COASTOX model as input to the RIVTOX model, which allows the COASTOX-RIVTOX-FDMA and COASTOX-RIVTOX-POSEIDON model chains to be used. According to the results obtained from the COASTOX simulation, simulations with the standard RIVTOX model give higher values for both nuclides, with a greater overestimation for Cs-137. However, this overestimation does not lead to significantly noticeable changes in the POSEIDON simulations, which results from the fact that the impact of river sources on the Baltic Sea is small, even for the highest concentrations in the river system.

The following calculation chains of the HDM subsystem of RODOS were therefore used to determine the doses and concentrations for releases of radioactive substances:

A. LSMC->RETRACE->RIVTOX->FDMA (inland water path).

B. LSMC-> RETRACE-> RIVTOX ->POSEIDON (marine path taking into account inland water contamination).

C. LSMC->COASTOX->RIVTOX->POSEIDON (special path with the COASTOX model for deposition on Lake Żarnowieckie).

The method of selecting meteorological sequences consisted of two steps:

- The use of meteorological data sets from three reference years (2005, 2010 and 2012 – it should be added that data from the 24-month monitoring period for Lubiatowo - Kopalino and Żarnowiec did not result in a change of the reference years). These sets were selected on the basis of the methodology for considering the most adverse meteorological conditions described in Volume V [Chapter V.1.13]. In general, the primary reference year for the largest exposures/depositions is 2010, but it was found more reasonable to consider the full set of sequences. This is due to the fact that from the point of view of surface water contamination it does not make sense to consider a number of weather sequences because the direction of movement of the radioactive cloud has little effect on the contamination of the largest water body, i.e. Lake Żarnowieckie or the contamination of coastal waters. Therefore, a preliminary selection of weather sequences was made. These sequences were divided into those that result in deposition to Lake Żarnowiec or coastal waters.
- From among such pre-selected meteorological sequences, those that result in the highest depositions in the considered area were selected. For this purpose, the short-range LSMC contamination transport and

dispersion model of the RODOS system was used. On this basis, sets of scenarios were prepared that provided the largest contribution to the doses. These are the sequences for the following dates: 01.01.2010, 02.09.1995, 10.01.2010, 04.03.2005, 23.01.2010, 31.03.2005. In addition, two scenarios were added for the dates: 10.02.2010 and 25.10.2012 selected as those that should generate the highest doses in Lake Żarnowieckie area – an additional assumption about the occurrence of precipitation was made, and the amount of radionuclide releases refers to an accident representative for emergency planning.

When modelling Lake Żarnowieckie, normal hydrological conditions were assumed. However, the situation was also considered when a pumped-storage power plant is in operation, which is located in the southern part of the lake. A special scenario was developed for such a situation – the following assumptions were made:

- Operation in the circadian rhythm for one month immediately following the accident and deposition of radionuclides.
- The following turbine pump duty cycle was assumed:

Time (hh : mm)	Volume flow rate, m3/s
00 : 00	0
04 : 40	700
09 : 20	0
14 : 00	-700
18 : 40	0

A linear flow between time segments is assumed. Negative flow means pumping water into the upper tank. This cycle is repeated daily.

1.3. Modelling of the spread of radioactive substances in groundwater

In the case of the AP1000 reactor, the direct release of radioactive substances into groundwater is practically excluded, both in the case of a bounding design basis accident and a severe accident considered in the extended design conditions, which is a severe accident considered in DEC and representative for emergency planning. Thus, groundwater can only be contaminated indirectly from deposition on the land surface of radioactive substances released into the air, and their transport in the ground to groundwater. For this reason, phenomena are modelled which involve the deposition of radioactive contamination from the air to the land surface and its transport in the ground to groundwater and then in groundwater to surface water.

A simplified model of radionuclide migration in GRANIS porous media, part of the PC-CREAM08 package, was used for the calculations. This model has a number of limitations, but it allows the concentrations of radionuclides in soil to a depth of 1 m to be calculated. Assuming that this corresponds to the groundwater level, the degree of its contamination can thus be assessed. Of course, this level may actually be lower, but given the fact that the rate of migration of radionuclides in the ground is lower than the rate of their migration in water, this assumption is conservative. In this sense, the results thus obtained constitute the upper limit of possible contamination values. As a standard, the GRANIS model produces concentrations on a horizontal cross-section (hence the Bq/m2 units). On the other hand, however, it gives information that the concentrations of activity are the same on horizontal cross-sections at depths from 0.30 m to 1 m. This actually means that the values provided are equal to volume concentrations. Scenarios were selected for calculations, for which the deposition around Lake Żarnowieckie was the largest. These are meteorological sequences for the following dates: 2005.10.05 at 18:00, 2005.09.22 at 20:00, 2010.01.13 at 12:00 and 2010.01.23 at 12. The date selection method was identical as for the models of the spread of contamination in surface water, save that it concerned depositions around Lake Żarnowieckie.

2. Modelling of the spread of radioactive substances and determination of doses at a distance of more than 30 km from the NPP, including the transboundary context

The methodologies described in this sub-chapter concern the analyses of radiological impacts presented in Volume IV [Chapter IV.18] and Volume V [Chapter V.4], i.e. impacts in the area above 30 km from the NPP for both site variants, within the country and abroad, respectively.

The basic models used for calculations were the models contained in the RODOS system [3], [4]. As previously described, RODOS is a comprehensive decision support system that can be used in national or regional emergency centres, providing consistent support in all accident phases, including long-term management of decontamination and remediation strategies for contaminated areas. It is used at various management levels in a number of European countries, such as Germany, Austria, Czechia, Finland, the Netherlands, Portugal, Romania, Slovakia, Ukraine, Hungary and Poland (it is used e.g. by the National Atomic Energy Agency). The system can support decisions on the introduction of a wide range of potentially effective remedial measures, including intervention and accident mitigation measures with regard to health, the environment and the economy. It can be used to analyse accidental releases of radioactive substances into the atmosphere and into various aquatic environments. There are also appropriate interfaces to local and national radiation monitoring systems, meteorological measurements and forecasts – for system adaptation to local, regional and national conditions.

As described in Volume V [Chapter V.1.13], the RODOS provides a comprehensive and continuously updated assessment of the exposure of the population to radiation following an emergency release of radioactive substances (or the threat of such release) into the atmosphere and/or the aquatic environment. The dispersion and deposition of substances released into the atmosphere is predicted by means of a nested chain of models. These models consistently simulate the processes of dispersion and deposition over two different ranges, the local scale within an area of up to 160 km, and the far range up to several thousand kilometres.

The models included in the RODOS package were selected from among many available models. The ones that best meet the operational requirements of the system were selected. The local scale model chain includes the RODOS Meteorological Pre-Processor RMPP [5], the RIMPUFF radioactive cloud dispersion model [6], the ATSTEP extended radioactive cloud dispersion model [7] and the DIPCOT Lagrangian model [8]. The models are described in Volume V [Chapter V.1.13].

MATCH is a long-distance model [9][9], [10]. It is also possible to use (with some limitations) the German Lagrangian model lDWD-L LASAT). The transfer of radionuclides from the radioactive cloud to food, as well as the resulting radiation exposure, are modelled in the terrestrial food chain and in the FDMT dose module [11]. The module is described in detail in Volume V [Chapter V.1.13].

Atmospheric dispersion models used in the RODOS system have been validated on the basis of experimental data and other models in many publications, e.g. [12], [13].

Two basic model types are used for mesoscale calculations: Lagrange and Euler models, or a combination of the two, as described below.

Lagrangian models

Lagrangian models [14] are a type of particle models based on the assumption that atmospheric diffusion can be modelled by Markov chains (random processes without memory). The development of computer technology combined Lagrangian particle models with mesoscale meteorological models simulating atmospheric circulation in complex terrain.

In Lagrangian particle models (LPDs), dispersion is modelled by simulating the motion of a large number of particles in an amount proportional to the intensity of pollution emissions. At the same time, or successively, the transmission of these particles by wind occurs. Models of a single particle moving at an average wind speed can be used to determine the average activity concentration. Estimation of higher-order statistical moments requires the use of a multi-particle model, where the ejection of a group of particles is simulated, whose turbulent component velocities are correlated. Generally, in models of this type, particle motion is treated as a stochastic process.

The advantage of Lagrangian models is their relatively easy adaptability for simulation in complex terrain areas, while the disadvantage is the need to track a very large number of particles in the case of long-term releases and the need to perform simulations over a large area.

Eulerian models

Unlike Lagrangian models, which track every particle in the medium, Eulerian models make calculations on local variables. The Eulerian approach is therefore characterised by that the simulations are performed on a computational grid, the proper selection of which, on the one hand, requires meeting the conditions of stability and, on the other hand, such a grid may include very large spatial scales, which is an advantage over Lagrangian models.

MATCH model (mixed)

The MATCH (Multi-scale Atmospheric Transport and Chemistry Model) is an offline model, which means that data from Numerical Weather Prediction System (NWPS) models is input data, and the model itself is independent of NWPS (as opposed to online models, where the dispersion model is coupled with the weather forecasting model, which is usually in fact a part of it). The version of the MATCH model implemented in the RODOS system is a semi-Eulerian-Lagrangian model because for the first phase the release is treated as a set of particles, and subsequently the data is projected onto the computational grid and considered in the form of a Eulerian model for further distances. This way, the advantages of both approaches are combined, as the particle model allows quick information to be obtained at small and medium distances, while the Eulerian model allows good modelling for large spatial scales. This method of implementation was chosen due to the basic use of the RODOS system to support the decision-making process in the event of emergency radionuclide releases. The basic elements of the implementation of the MATCH model in the RODOS system are as follows [10]:

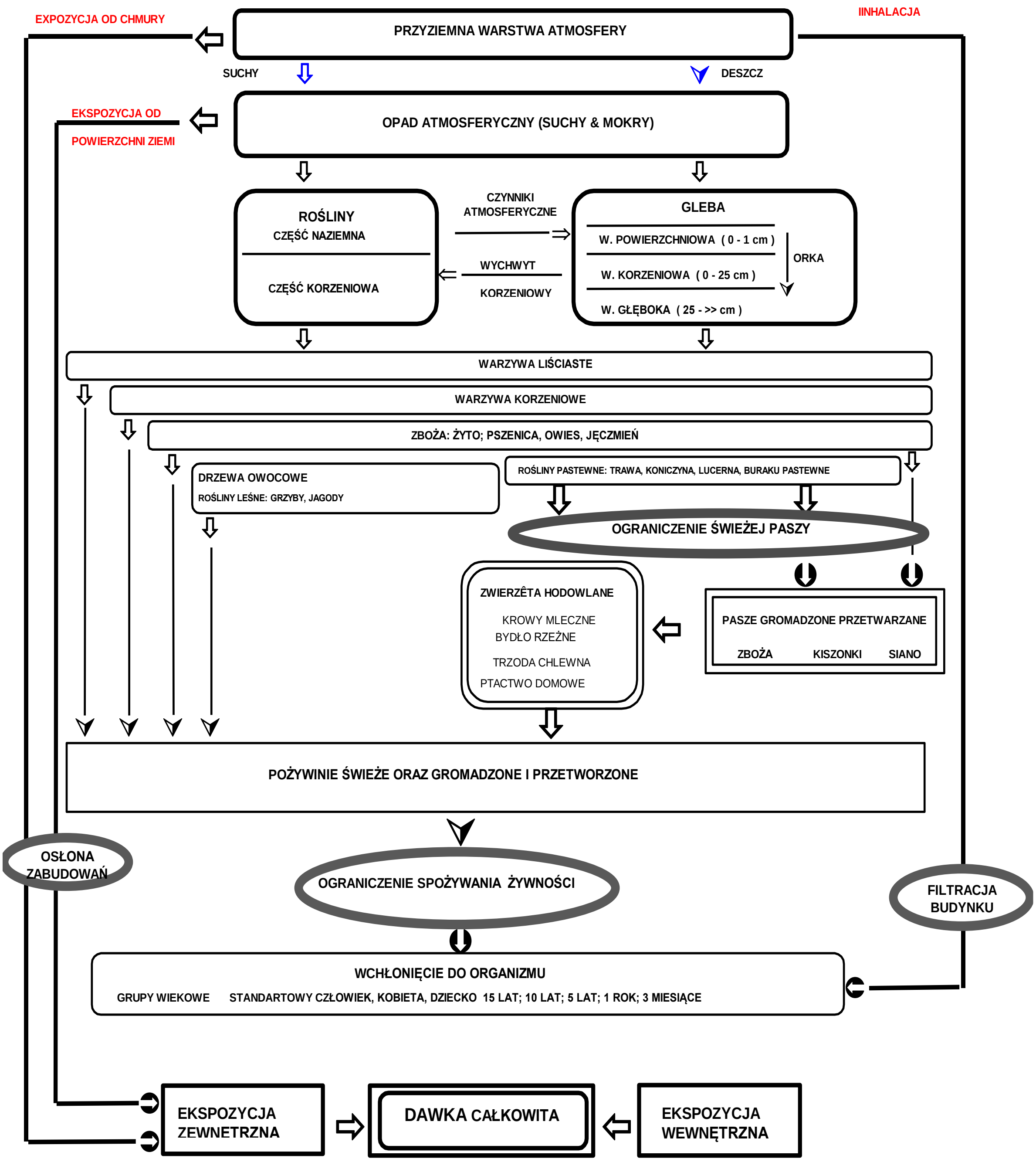
- the possibility of using the source terms database of the RODOS system or the determination of releases by the user,
- the possibility of combination with short-range dispersion models of the RODOS system,
- application of the RODOS system interface for data entry and presentation of results, data export, preparation of reports, etc.,
- adaptation of the MATCH model to include different types and formats of meteorological data and the meteorological pre-processor of the RODOS system, allowing the inclusion of information on turbulent kinetic energy, as well as terrain coverage data contained in the GIS databases of the RODOS system, in order to determine the structure of the boundary layer.

Like any RODOS calculation module, MATCH was validated in a number of experiments (e.g. ETEX-1, ETEX-2) and comparative tests carried out by the UE ENSEMBLE project (https://ensemble.jrc.ec.europa.eu).

FDMT food chain and dose module [for terrestrial pathways]

For the FDMT model, the pathways of a radionuclide in the human environment are illustrated by [Figure V.1.16-1-1], which shows the main components of the human ecosystem, with the possible pathways of radionuclide transport marked. Dynamic transport processes, i.e. changing over time continuously, are depicted with double arrows ⇒, discrete transport processes, changing suddenly, are marked with single arrows ➢, processes "controlled" as a result of countermeasures are presented with double arrows on a black background ➲. Possible ways of dose reduction are shown in [Figure V.1.16-1-1] in oval fields. Based on data on the concentration of radionuclides in the near-ground air and data on atmospheric conditions, the model calculates the amount of radionuclide deposition on the ground surface, and then the time series of radionuclide concentrations in individual elements of the human terrestrial ecosystem, i.e. in soil, crop and fodder plants, livestock tissues and animal products such as milk and meat, both with short-term and continuous types of contamination. The model takes into account most of the important dynamic processes occurring in the ecosystem, such as the uptake of contamination by the leaf surface and the removal of contamination by atmospheric factors (weathering), the growth dynamics of various plant species, the passage of contamination from soil to plant through the root system, the leaching of contamination from the soil and radioactive decay. The variability of certain parameters depending on the season in which the contamination occurred is also taken into account, e.g. changes in plant biomass or livestock feed, as well as different harvesting periods and soil cultivation methods. With the help of this model, it is possible to obtain an assessment of doses in the selected time interval from: external exposure (based on the values of total precipitation of a given isotope to the earth surface calculated by the program), inhalation (based on data on the concentration of a given radionuclide in the air), taking into account the resuspension of radioactive substances in the air and assessment of effective ingestion dose equivalents.

As mentioned, the FDMT model is described in detail in Volume V [Chapter V.1.13].



Expozycja od chmury	Exposure from cloud
Ekspozycja od powierzchni ziemi	Exposure from ground surface
Suchy	Dry
Przyziemna warstwa atmosfery	Bottom layer of atmosphere
Deszcz	Rain
Inhalacja	Inhalation
Opad atmosferyczny (suchy & mokry)	Precipitation (dry & wet)
Rośliny	Plants
Część naziemna	Above-ground part
Część korzeniowa	Root part
Czynniki atmosferyczne	Atmospheric factors
Wychwyt korzeniowy	Root capture
Gleba	Soil
Orka	Tillage
W. Powierzchniowa (0 - 1 cm)	Surface layer (0 - 1 cm)
W. Korze mowa (0 - 25 cm)	Root layer (0 - 25 cm)

W. Głęboka (25 - >> cm)	Deep layer (25 - >> cm)
Warzywa liściaste	Leafy vegetables
Warzywa korzeniowe	Root vegetables
Zboża: żyto; pszenica, owies, jęczmień	Cereals: rye, wheat, oats, barley
Drzewa owocowe	Fruit trees
Rośliny leśne: grzyby, jagody	Forest plants: mushroom, berries
Rośliny pastewne: trawa, kończyna, lucerna, buraki pastewne	Forage: grass, clover, medick, fodder beet
Ograniczenie świeżej paszy	Reduction of fresh fodder
Zwierzeta hodowlane	Livestock
Krowy mleczne	Dairy cattle
Bydło rzezie	Slaughter cattle
Trzoda chlewna	Pigs
Ptactwo domowe	Poultry
Pasze gromadzone przetwarzane	Stored processed forages
Zboża	Cereals
Kiszonki	Silage
Siano	Hay
Pożywinie świeże oraz gromadzone i przetworzone	Fresh, stored and processed food
Osłona zabudowań	Shielding of buildings
Ograniczenie spożywania żywności	Reduction of food consumption
Filtracja budynku	Building filtration
Wchłonięcie do organizmu	Absorption into body
Grupy wekowe	Age groups
Stadartowy człowiek, kobieta, dziecko 15 lat; 10 lat; 5 lat; 1 rok; 3 miesiące	Standard man, woman, child 15 years; 10 years' 5 years; 1 year; 3 months
Ekspozycja zewnętrzna	External dose
Dawka całkowita	Total dose
Ekspozycja wewnętrzna	Internal exposure

Figure V.1.16-1-1 Radionuclide pathways through the terrestrial environment to humans

Source: [15]

3. Trajectory analysis and preparation of meteorological data

Trajectory analysis for the spread of radionuclides and preparation of meteorological data was carried out by the Institute of Meteorology and Water Management (IMGW), which normally sends daily meteorological data to the PAA Centre for Radiological Events, adapted for use in the RODOS system.

On the basis of data available from 2005–2014, time sequences of the state of the atmosphere were selected, which, in the event of release of radioactive substances into the atmosphere, lead to the fastest arrival of the contamination cloud to selected receptors, i.e. to the borders of neighbouring countries or located around Poland. A complete list of receptors is provided in [Appendix V.1.13-2], including estimates of the shortest cloud arrival times, assuming an accident at either of the two NPP sites under consideration. These times should be taken as indicative – in particular, they do not mean that radioactive contamination will occur at these moments – but only that there may be specific weather conditions that allow the cloud to arrive in specified time. In the case of Denmark, the island of Bornholm was treated as a separate receptor due to its significantly smaller distance to potential NPP sites than the rest of the country.

Meteorological data and trajectories of the movement of the radioactive cloud transfer over the entire area under consideration were analysed using the COSMO meteorological model (used in IMGW for weather forecasting). The grid of nodes in the domain has a spatial resolution of 14 km and consists of 193×161 grid cells in the X and Y directions, respectively, which means an approximate size of the entire domain of 2700×2250 km.

The trajectory analysis was carried out in two stages:

STAGE 1:

Meteorological data covering a period of ten years (2005-2014) was prepared and pre-processed. This dataset consists of the results of calculations using the global meteorological model GME (Global Model Ersatz, launched at Deutscher Wetterdienst (DWD), in Offenbach, Germany), processed using the regional meteorological model COSMO (Consortium for Small-Scale Modelling). So it is a different dataset than the local data used for modelling over shorter distances. The main part of the data used consisted of three-dimensional wind fields, every three hours at ten hybrid levels of the COSMO model (approximately from 10 meters to about 3 kilometres above ground level). In analyses of this type, only one level is often selected for simulation, which represents the level of mass transport of pollutants in the atmospheric boundary layer, which in fact ultimately reduces the whole issue to a two-dimensional problem. However, to obtain a complete picture of the trajectory dispersion, full 3D wind fields were used in this analysis for modelling.

STAGE 2

Appropriately processed wind fields were used to calculate 10-day trajectories coming from a specific nuclear power plant site at ten hybrid levels of the COSMO model, which can generally be taken as the average effective emission level [16]in a hypothetical accident and contamination emission scenario. One trajectory was analysed every ten minutes every hour for a period of ten years. The time between consecutive points on each trajectory was 10 minutes, to ensure the basic stability condition that the distance between two consecutive points is smaller than the grid cell, i.e. 14 km. In total, more than half a million trajectories were calculated at each level between 2005 and 2014. The methodology for calculating the trajectory was identical to that of the example study [17], but it was extended to a three-dimensional problem.

RESULTS – TRAJECTORY ANALYSIS

The main objective of the trajectory analysis in this study was to select the worst-case (from a meteorological point of view) scenarios in the event of a severe accident representative for emergency planning purposes , in the planned Polish Nuclear Power Plant, at the Lubiatowo - Kopalino or Żarnowiec site.

The selection of worst-case meteorological scenarios was based on results that include the analysis of trajectories reaching selected receptors the fastest. The aim was to answer the question of what the shortest time of arrival of a radioactive cloud to specific receptor sites would be, which would in turn allow the most likely meteorological scenarios to be identified leading to the highest doses at specific sites.

To answer this question, the shortest time for the trajectory to reach the receptor was calculated in three stages. First, the number of points on the trajectory, coming out of the selected nuclear power plant site and reaching a specific grid cell (that is, the place where the receptor is located), was calculated. For each trajectory, the calculations started with the second point to omit the first point of the trajectory, that is, the exact location of the nuclear power plant site. Then, in order to calculate the time of arrival of the trajectory, the number of points between the power plant site location and the target grid cell was multiplied by the time step of the trajectory. In the end, the shortest time to reach the receptor from the source was chosen from all the recorded arrival times.

A full list of the dates/times of release of the fastest trajectories, starting from the assumed ten levels (as described above for the steps of trajectory analysis), for all scheduled source-receptor pairs over a ten-year period, is given in [Appendix V.1.13-2].

PREPARATION OF METEOROLOGICAL DATA FOR THE MATCH MODEL

For selected dates from [Appendix V.1.13-2], meteorological data sets have been prepared for simulation using the RODOS MATCH model. For this purpose, recalculations were first made with the COSMO model with the use of archival initial and boundary conditions from the period 2005 to 2014. Then, using a dedicated application, the results of the COSMO model were transformed into a form compliant with the MATCH model specification.

Each file contains the following data:

- Structure of levels (height above sea level ASL [m], hybrid level σ)
- Land coverage (land=1, water=0), [5]
- At 35 vertical levels:
  - Horizontal components of wind speed u and V [m/s]
  - Air temperature [K]
  - Relative humidity [kg/kg]
- At ground level:
  - Pressure [Pa]
  - Cumulative snowfall [kg/m^2]
  - Total cloudiness [%]
  - Albedo [%]
  - Total precipitation [kg/m^2]
  - Roughness of the Earth’s surface [m]
  - Air temperature at the ground [K].

In general, for each day, 9 files were obtained in GRIB-1 format (Gridded-Binary v.1), at a time resolution of three hours.

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