Consortium
Pöyry Energy Oy
Lithuanian Energy Institute

Environmental Impact Assessment Report
New Nuclear Power Plant in Lithuania
27 March 2009

Organizer of proposed economic activity: **Visagino atomine elektrine, UAB**

Developer of EIA report: **Pöyry Energy Oy (Finland)**
Lithuanian Energy Institute (Lithuania)

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(Final Report)

Organizer of proposed economic activity:	**Visagino atomine elektrine, UAB**
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BI – Institute of Botany;
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LEI – Lithuanian Energy Institute;
LMED – Lithuanian Association of Metalecology;
NVSPL –The National Laboratory of the Public Health Care.

TABLE OF REVISIONS

Issue	Date	Description
Issue 1	24 July 2008	Submitted to the Organizer of proposed economic activity
Issue 2	27 August 2008	Submitted to public and foreign countries review
Issue 3	22 October 2008	Supplemented and updated according public comments and submitted to EIA relevant parties for review
Issue 4	22 December 2008	Supplemented and updated according comments of EIA relevant parties and re-submitted to EIA relevant parties
Issue 4A	22 January 2009	Updated according to final comments of EIA relevant parties and appendix containing documents on public informing and public participation in the EIA process, official letters and conclusions from EIA Relevant parties and EIA developer's responses to comments from public and EIA parties
Issue 5	27 March 2009	Supplemented and updated according to comments of the Ministry of Environment

GLOSSARY AND ABBREVIATIONS

Activity	The quantity A for an amount of radionuclide in a given energy state at a given time, defined as $A=dN/dt$, where dN is the expectation value of the number of spontaneous nuclear transformations from the given energy state in the time interval dt. The unit of activity is the s^{-1}, termed the Becquerel (Bq), 1 Bq = 1 s^{-1}.
Aerosol	Small floating particle.
AGIR	AGIR (automatic registers of gamma intensity in air) are Lithuanian automatic radiation monitoring stations.
ALARA	As Low As Reasonable Achievable. This is an internationally recognized acronym which requires that the radiation dose to personnel which results from work with radioactive substances is minimized to the greatest possible extent, except where the additional cost or impracticality of further dose-reduction measures would be unreasonable when compared to the additional dose-reduction obtained by the adoption of those measures. The ALARA principle is progressively used in environmental issues as well.
Alpha/ beta/ gamma emitters	Nuclei that emit alpha, beta or gamma type of ionizing radiation.
Aquifer	An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.
Background contamination	Levels of hazardous substances in the environment that are either naturally occurring, from an off-site source or a result of general contamination in the area.
bar	A unit of pressure. 1 bar = 100 000 Pascal (Pa). Atmospheric pressure is approximately 1 bar.
BDBA (Beyond Design Basis Accident)	An accident considerably more severe than a design basis accident, yet not involving core degradation.
Bq, Becquerel	The SI unit of activity, equal to one transformation per second.
C-14, carbon-14	In addition to radon, the Carbon-14 isotope is the most significant source of radiation exposure in a uranium fuel cycle.
Cloud shine	Exposure to gamma radiation from radioactive materials in an airborne plume.
Collective dose	Product of the number of persons of the exposed population group and the average dose per person; unit manSievert [manSv].
Condenser	Condenser converts and recovers the steam that passes through the turbine from its gaseous to its liquid state.
Cooling water	Cooling water is sea/lake/river water used in a condenser for cooling the steam coming from the turbines back to water. Cooling water does not come into contact or mix with the process waters of the nuclear power plant.
D&D	Decontamination & Decommissioning.
DBA (Design Basis Accident)	An accident during which the parameters determined in the design and damage of nuclear fuel are kept within authorized limits, and the release of radionuclides into the environment does not exceed activity limits, determined in the design.
Design basis external event	External event (-s) or combination of external events, considered during the development of a nuclear facility design.
DCD	Design control documentation.
Deuterium	Isotope of hydrogen which nucleus contains one proton and one neutron.
Direct cooling system (DC)	Cooling water is taken from water reserve (e.g. lake), led through a heat exchanger and the warmed water is discharged back to the reserve.
E.ON	E.ON AG; Germany based energy corporation.
EDF	Electricité de France.

Effective dose	Includes both external (cloud shine and ground shine) and internal (inhalation and ingestion) dose.
Efficiency	The ratio of the amount of electric energy produced by a power plant to the amount of energy contained in the consumed fuel.
EIA	Environmental impact assessment.
Electrical power	The rate at which electrical energy is generated at power plant.
EnBW	Energie Baden-Württemberg AG.
Enrichment	Concentration of a substance. Before enrichment, uranium is converted in gaseous form through chemical processes to uranium hexafluoride (UF_6). The enrichment of uranium hexafluoride is executed either by gas diffusion or nowadays increasingly by centrifuge methods by utilizing chemical and physical characteristic of the uranium.
Environmental Management System (EMS)	EMS serves as a tool to improve environmental performance. Defined in ISO 14001 standard. Provides a systematic way of managing an organization’s environmental affairs and is the aspect of the organization’s overall management structure that addresses immediate and long-term impacts of its products, services and processes on the environment.
EPA (Environmental Protection Agency)	State budget institution, the purpose whereof is to collect, analyze and provide reliable information on the state of the environment, flows of chemicals and pollution prevention measures, as well as to ensure the organization of water preservation and management in order to achieve the objectives of water protection.
Equivalent dose	The absorbed dose adjusted for the relative biological effect of the type of radiation being measured.
EUR (European Utilities Requirements document)	the European Utility Requirements (EUR) document aim at harmonisation and stabilisation of the conditions in which the standardised LWR nuclear power plants to be built in Europe.
Eutrophication	Change of ecosystem induced by an increase in nutrients in an ecosystem.
External exposure	The dose that Includes the dose from cloud shine and the dose from ground shine.
Fission	The splitting of a heavy atomic nucleus into two parts, accompanied by the release of fast neutrons.
FMI	Finnish Meteorological Institute.
Fujita classification	A scale for rating tornado intensity, based on the damage tornadoes inflict on human-built structures and vegetation. Scale: F0-F12. F0 corresponds to wind speed of 64-116 km/h. F12 is equal to 1 Mach.
Gaseous radioactive emissions	Radioactive material particles released from the source to atmosphere.
GE	General Electric Company.
Ground shine	Exposure to gamma radiation from radioactive materials deposited on ground.
Half-life	The time it takes for the amount of radioactive matter to be reduced to half as a result of radioactive decay, i.e. as half the matter is converted into another type of matter.
Heavy water	Heavy water is chemically the same as regular (light) water, but with the two hydrogen atoms (as in H_2O) replaced with deuterium atoms (hence the symbol D_2O). Deuterium is an isotope of hydrogen; it has one extra neutron.
HVAC	Heating, Ventilating and Air Conditioning.
IAEA	International Atomic Energy Agency, The IAEA is the world’s centre of cooperation in the nuclear field. The Agency works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies.

INES	International Nuclear Event Scale is used for facilitating rapid communication to the media and the public regarding the safety significance of events at all nuclear installations associated with the civil nuclear industry, including events involving the use of radiation sources and the transport of radioactive materials.
INPP	Ignalina nuclear power plant.
Integrated Monitoring (IM)	Simultaneous measurement of physical, chemical and biological properties of an ecosystem over time and across compartments at the same location.
Internal exposure	The dose due to inhalation or ingestion of radioactive material.
InterRAS	Computer software for assessing the implications of nuclear accidents used in the first phase of an emergency.
Ionising radiation	Radiation capable of producing ion pairs with differing charges in the biological environment.
ISO 14001 standard	International voluntary standard describing specific requirements for an EMS (Environmental management system). ISO 14001 is a specification standard to which an organization may receive certification or registration. Published by International Organization of Standardization.
Isotope	Atoms of the same element differing from each other in the number of neutrons in their nucleus. Almost all natural elements occur as more than one isotope.
Isotope-specific analysis	Analysis of masses by mass spectrometry and neutron activation analysis and analysis of radiation from the atom, as is done by α-, β-, γ– and sometimes X-Ray spectrometry.
Light water	Regular water, H_2O.
LOCA	Loss Of Coolant Accident.
LRDB	Lithuanian Red Data Book serves as a legal document on which the protection of rare and endangered plant, fungi and animal is based.
LULUCF (Land use, land use change and forestry)	Tree-planting projects, reforestation and afforestation, designed to remove carbon from the atmosphere.
Maintenance	Complex of planned and systematically implemented activities aimed at ensuring reliable operation of systems (components) and maintaining their design characteristics within their design lives. Maintenance includes general service, overhaul, medium and current repair works, replacement of spares and design modifications of systems (components), as well as tests, inspections and calibration whenever necessary.
Mansievert (manSv)	A unit of collective dose. If, for example, each person in a population of 1000 members receives an average radiation dose of 20 millisieverts, the collective dose is 1000 x 0.02 Sv = 20 manSv.
ME (Ministry of Environment)	Ministry of Environment coordinates the EIA procedure, provides information about the EIA process to foreign countries and takes a motivated decision whether a proposed economic activity is permissible on a chosen site.
Monitoring zone	An area in which monitoring is performed.
MOX fuel	Mixed oxide fuel. Blend of oxides of plutonium and natural uranium, reprocessed uranium, or depleted uranium.
MW, megawatt	A unit of power (1 MW = 1 000 kW).
$MW_{Released}$	The amount of thermal energy released to the lake in direct cooling (or dissipated to air in cooling towers). Calculated from the total amount of energy produced (thermal and electrical) by assuming plant efficiency of 35 %.
MWd/MTU	The energy produced per initial unit of nuclear fuel weight.
NNPP	New nuclear power plant.

Nuclear fission	Nuclear reaction of a heavy atomic nucleus and neutron which leads to subdivision of nucleus into two fragments and producing 2-3 fast neutrons.
Nuclear fuel	Nuclear materials used for nuclear power generation.
Nuclear materials	Any metal alloy, chemical compound or material mixture which contains plutonium, uranium (enriched in the isotope 235 or 233; or depleted) and thorium.
Nuclear Power Plant (NPP)	A complex of equipment and buildings intended for generating electricity or electricity and heat by using nuclear fuel.
N/A	Not applicable.
Precipitation	Any product of the condensation of atmospheric water vapour that is deposited on the earth's surface.
Project implementing company	Project implementing company is responsible for carrying out project implementation activities in compliance with the safety requirements imposed on nuclear activities. Having fulfilled the requirements laid down in legal acts and having received authorisations and licences, the project implementing company become the operator of the nuclear power plant and expands electricity generating capacities in accordance with the procedure laid down by legal acts. (ref. The Republic of Lithuania Law on the Nuclear Power Plant, State Journal, 2007, No. 76-3004).
The organiser of the proposed economic activity	Organization, which is responsible for the proposed economic activity (Visagino atomine elektrine, UAB). After the amendments of the Law of the Republic of Lithuania on the Nuclear Power Plant had been adopted and the Joint Stock Company “Visagino atomine elektrine, UAB” had been established, “Visagino atomine elektrine, UAB” took over all the preparatory works including the EIA procedure of NNPP which initially was organized by “Lietuvos energija AB” in spring of 2007.
Radiation	
Alpha	Alpha radiation is of positively-charged particles emitted from the nucleus of an atom. Alpha particles are helium nuclei, with 2 protons and 2 neutrons.
Beta	Particle radiation consisting of electrons or positrons.
Gamma	Gamma radiation is radiation travelling as electromagnetic waves whose wavelength is smaller and energy higher than those of X-rays.
Radioactive emissions	Radioactive pollutant in gaseous form, as aerosols, liquids or in other form released into environment.
Radioactive materials	Material containing one or more radionuclides which activities must be considered from the point of radiation protection.
Radioactive noble gases (RNG)	The noble gases are helium (He), neon (Ne) argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). Some of these isotopes are radioactive. The permanent activity monitoring of radioactive noble gases (Ar-41, Kr-85, Kr-85m, Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135m, Xe-135, Xe-138) released to atmosphere at Ignalina NPP is performed.
Radioactive waste	Spent nuclear fuel and other materials for which no further use is foreseen and which contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels.
Radioactivity	Transformation of an atomic nucleus into other nuclei. A radioactive nucleus emits radiation characteristic to the transformation (alpha, beta or gamma radiation).
Radionuclides	An unstable form of a nuclide.
RADIS	Automatic Measurement Systems Division. Maintains the automatic gamma-monitoring network and the mobile radiological laboratory.
RBMK	*Reaktor bolshoy moshchnosti kanalniy* is a Russian water-cooled graphite-moderated channel-type reactor type used in INPP.
Reactor types	
CANDU reactor	CANDU (CANada Deuterium Uranium) is a pressurized heavy water reactor which uses natural uranium (0.72% U-235) as a fuel and heavy

	water for cooling and neutron moderation.
ACR	The Advanced CANDU Reactor can be considered as a hybrid form of PWR, having a different reactor design. It is a light-water-cooled reactor that incorporates features of both Pressurised Heavy Water Reactors (HWR) and Advanced Pressurized Water Reactors (APWR) technologies.
BWR	Boiling Water Reactor: A light-water reactor in which water used as the coolant boils as it passes through the reactor core. The resulting steam is used for driving a turbine.
HWR	Heavy-Water Reactor in which heavy water is kept under pressure in order to raise its boiling point, allowing it to be heated to higher temperatures and thereby carry more heat out of the reactor core.
LWR	Light Water Reactor: Reactor type in which regular water is used for cooling and as a moderator. Most nuclear power plant reactors in the world are light water reactors.
EPR	European Pressurized Reactor.
PWR	Pressurized Water Reactor: A light-water reactor in which the water used as coolant and neutron moderator is kept under such a high pressure that prevents it from boiling regardless of the 300°C temperature. The water that has passed through the reactor core releases its heat to the secondary circuit water in separate steam generators. It boils into steam that is used for driving a turbine.
RWE	RWE AG; Germany based energy corporation.
SA	Severe Accident.
SAC	Special Area of Conversation.
Severe accident	An accident considerably more severe than a design basis accident involving significant core degradation.
SPZ	Sanitary Protection Zone: A special territory or a site of radioactive contamination where the irradiation level may exceed the prescribed norms under normal operational conditions of a nuclear facility.
SAR	Safety Analysis Report.
SCI	Sites of Community Importance.
SILAM	Air Quality and Emergency Modelling System SILAM of the Finnish Meteorological Institute.
SPA	Special Protection Area.
Specific activity	Ratio of the sample's activity and its mass (unit – Bq/kg).
SNF	Spent Nuclear Fuel: Nuclear fuel irradiated in the active zone of a reactor if the organisation operating the reactor officially registers following the procedures set by the state or state delegated authority and/or the supervising institutions that the fuel will no longer be used in reactors.
Sv, Sievert	An ionising radiation dose unit indicating the biological effects of ionising radiation. As it is a very large unit, millisieverts (1 mSv = 0.001 Sv) and microsieverts (1 µSv = 0.001 mSv) are more commonly used.
Thermal power	The rate at which thermal energy is generated in the reactor.
TLD stations	Thermoluminescent Dosimeter (TLD) stations are used to measure external radiation exposure rates in the site.
Tritium	Radioactive isotope of hydrogen (H-3). The nucleus of tritium contains one proton and two neutrons.
TWh	Terawatt/hour: A unit of energy. One terawatt-hour equals one billion kilowatt/hours or one thousand gigawatt/hours.
UK HSE	United Kingdom Health and Safety Executive.
UNECE, United Nations Economic Commission for Europe	Founded in 1947, UNECE, the United Nations Economic Commission for Europe, is one of the five regional commissions of the United Nations. Its aim is to strengthen the economic cooperation between its member countries.
UO_2	Uranium dioxide.

Uranium	An element with the chemical symbol U. Uranium comprises 0.0004% of the earth's crust (four grammas in a ton). All uranium isotopes are radioactive. Natural uranium is mostly in the form of isotope U-238, which has a half-life of 4.5 billion years. Only 0.72% of natural uranium is in the form of isotope U-235, which is used in nuclear fission reactions in nuclear reactors and nuclear weapons.
US NRC	United States Nuclear Regulatory Commission.
VATESI	State Nuclear Power Safety Inspectorate (www.vatesi.lt).
Waterborne releases	Radioactive effluents, released to environment.
WWTP	Waste water treatment plant.
Yellowcake	Uranium concentrate; U_3O_8 (triuranium oxide).
Zircaloy	Group of high-zirconium alloys. Mainly used as cladding of fuel rods.

CONTENTS

Geological maps by permission of Lithuanian Geological Survey.

SUMMARY

During spring of year 2007, "Lietuvos Energija AB" started an Environmental Impact Assessment (EIA) procedure for the construction of a new nuclear power plant (NNPP) to be located next to the present Ignalina nuclear power plant (INPP). After the amendments of the Law of the Republic of Lithuania on the Nuclear Power Plant had been adopted and the Joint Stock Company "Visagino atomine elektrine, UAB" had been established, the later took over all the preparatory works including the EIA procedure of NNPP.

Lithuania has no primary energy sources of its own. From the late 1980s, the Ignalina nuclear power plant (INPP) has produced the majority of Lithuania's electricity. The Lithuanian electricity and gas networks are closely interconnected to the north-west power sectors of the Russian Federation.

The meeting of the finance ministers from the group of seven industrialized nations of the world in Munich in 1992 was crucial to Lithuania and operation at INPP. The political decision was made that its RBMK reactors should be closed, as the reactors were judged incapable of being upgraded to western safety levels.

Presently the INPP is the only nuclear power plant in Lithuania. About 70 % of the total domestic electricity production was generated by the INPP in 2005. The current Lithuanian electricity generating capacities, including small capacity combined heat and power plants that are planned to be constructed, will be sufficient to meet the national power demand from the shutdown of INPP Unit 2 by at end of 2009 until 2013. The NNPP would become the major electricity generating source in Lithuania when commissioned.

THE ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE (EIA)

The EIA is a prerequisite for the construction of such an important installation as the NNPP. It has to describe how the plant will influence the surrounding environment and evaluate whether the impacts of the project are environmentally and socially acceptable. Only after the EIA has been exposed to the local and international communities and approved by the Lithuanian Ministry of Environment can the project proceed to the authorisation process.

Based on Lithuanian regulations, the EIA procedure first involves preparation of an EIA Program (EIAP), which has to give the structure of the EIA and a description of the topics that will be studied and the methods to be employed. Based on the EIA Program, terms set by the Ministry of Environment, and received comments, an EIA Report (EIAR) is prepared, which describes the environment and assesses the environmental and social impacts of the project. The main stages of the EIA procedure are presented in Figure 1.

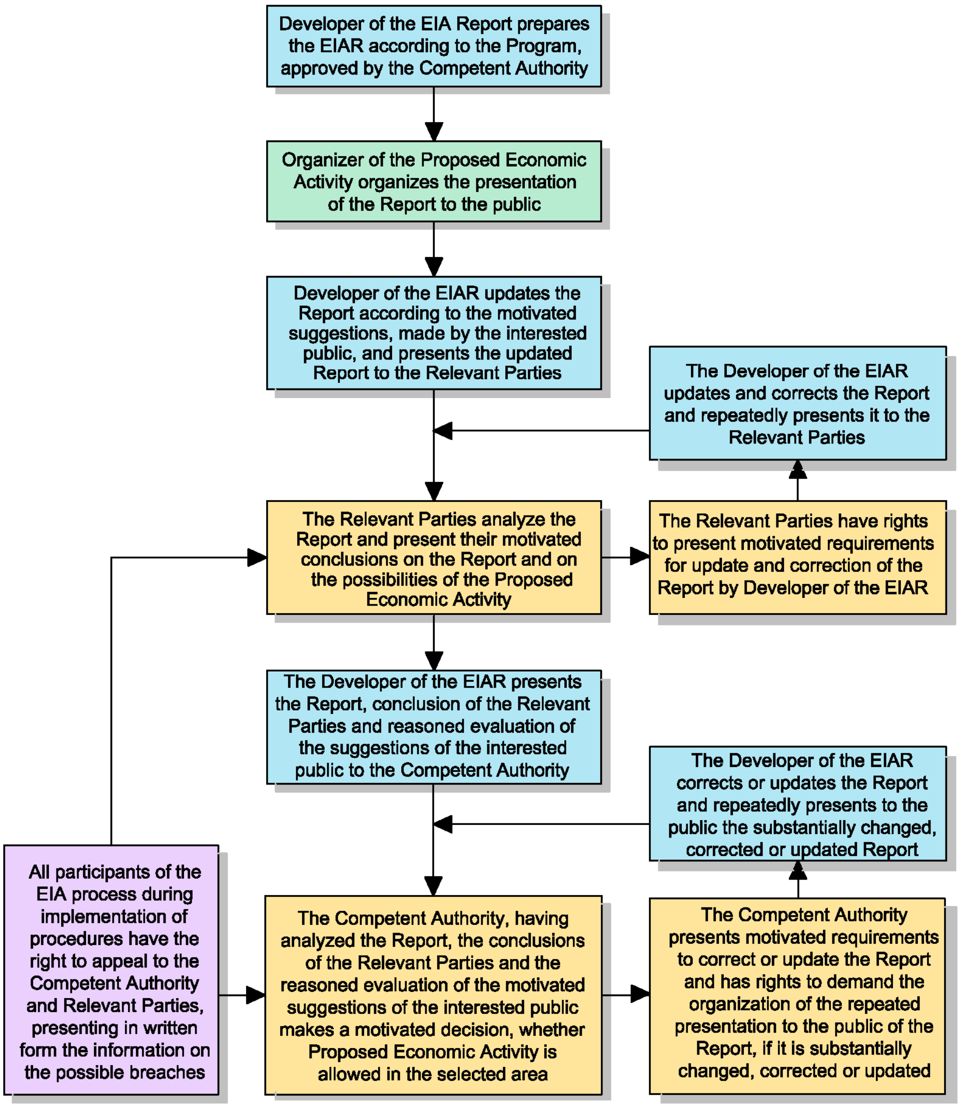

Figure 1. The main stages of the EIA procedure.

The EIA Program for the NNPP was published July 26th, 2007, and it was approved by the Lithuanian Ministry of Environment on November 15th, 2007 after extensive national and international commenting. The EIA Program for the NNPP was prepared by an international consortium consisting of Pöyry Energy Oy and the Lithuanian Energy Institute (LEI).

THE PURPOSE, LOCATION AND SCHEDULE OF THE PROJECT

The project assessed in this EIA Report is the construction of a new nuclear power plant (NNPP) in the near vicinity of the present Ignalina nuclear power plant (INPP), in the municipality of Visaginas on the shore of Lake Druksiai in north-eastern Lithuania (see Figure 2). The INPP is the main electricity source for Lithuania at the moment, but, as a condition of entry in the European Union, the Lithuanian government has agreed on shutting down the INPP since it does not meet the required safety standard conditions. The first unit of INPP was shut down in 2004, the second is still in operation and is to be shut down by the end of 2009. In order to face this electricity gap, the Lithuanian government started the decisional process for the construction of a new and safer regional NPP, capable of supplying also part of the neighbouring countries' needs for electricity.

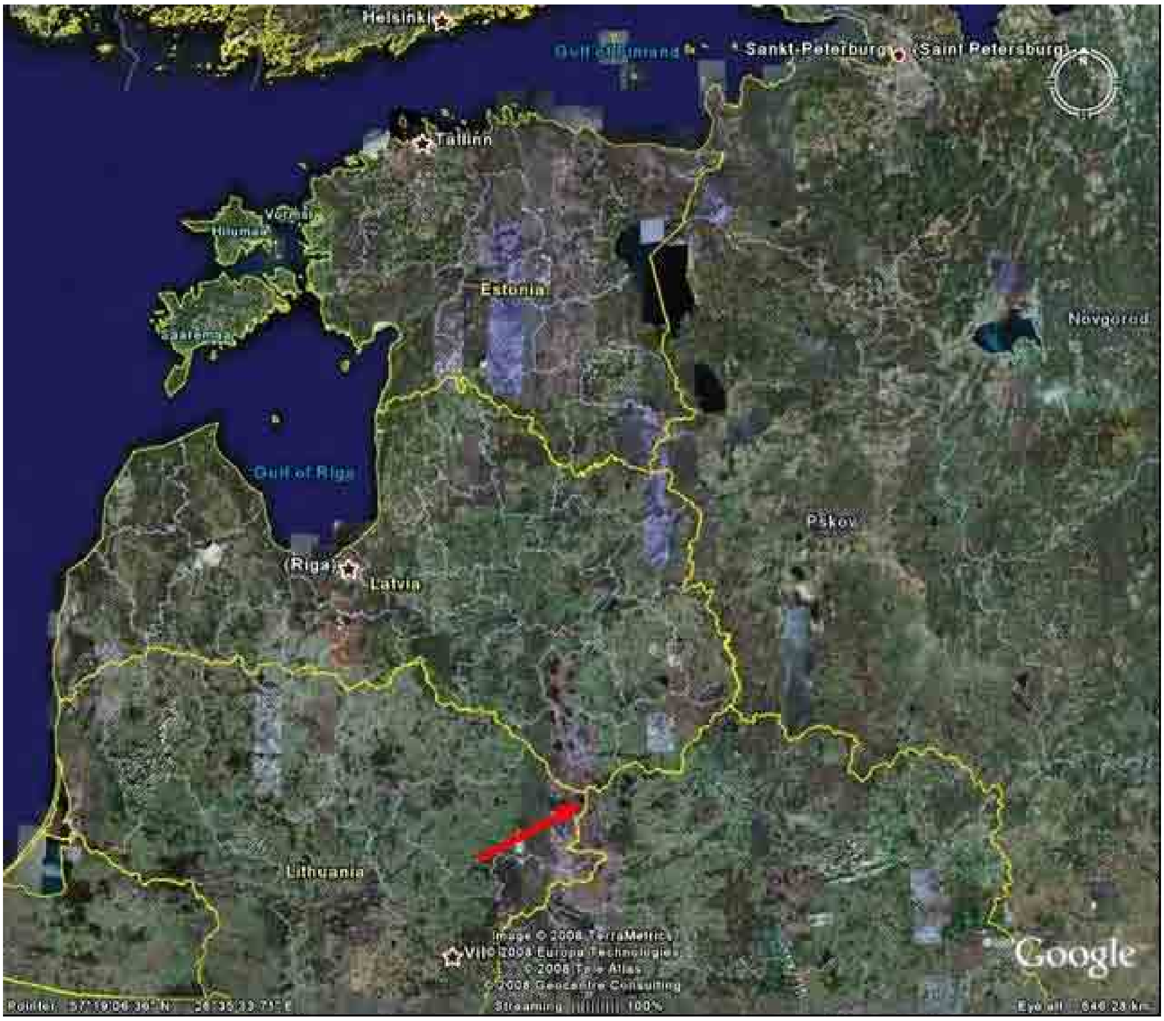

Figure 2. Location of the NNPP project area.

The scheduled construction time for the new NPP is around 8-9 years from the start of the EIA procedure. This would mean 2015 as the earliest year for commissioning of the NNPP, which would match the forecasts of the Lithuanian National Energy Strategy.

PROJECT OPTIONS AND LIMITATIONS

There are two potential sites for the construction of the new NPP, both located on the shore of Lake Druksiai: Site No. 1 is situated east of Ignalina NPP and Site No. 2 is situated west of the existing INPP switchyard (see Figure 3).

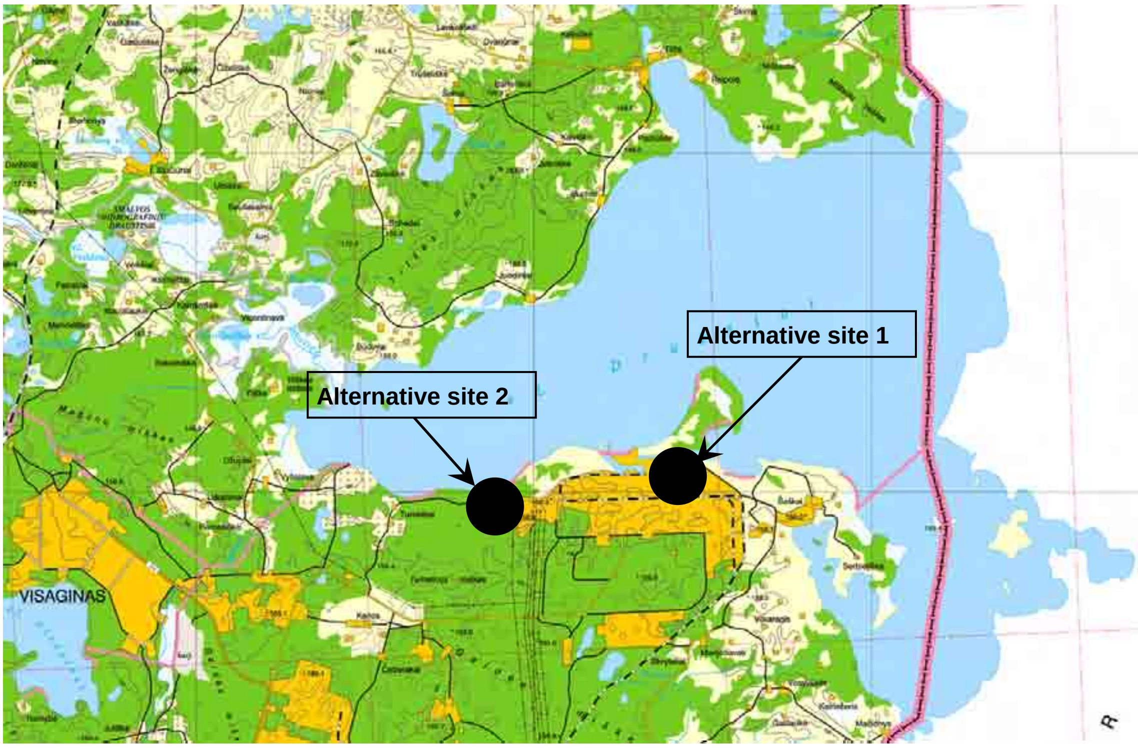

Figure 3. The proposed sites for the new NPP on the shore of Lake Druksiai.

The choice of technology to be adopted in the new NPP is still open. All the suitable main reactor technologies (Boiling Water Reactor, Pressurized Water Reactor and Pressurized Heavy Water Reactor) have been evaluated in this EIA Report, considering different vendors, different power levels, the two site alternatives for the construction of the plant and different cooling alternatives. The maximum power output of the NNPP discussed in this EIA Report is 3 400 MW, with the number of reactors varying from 2 to 5 depending on the technological alternatives and total electrical power to be constructed. Different cooling system options have also been studied and the cooling capacity of and impacts on Lake Druksiai has been assessed.

LINKS TO OTHER PROJECTS AND PLANS

The new NPP will be erected next to Ignalina NPP, but will be operated by a different company. The location next to INPP provides the opportunity to utilise existing infrastructure, whenever this is feasible. This existing infrastructure that can possibly be utilised includes among others the cooling water inlet and outlet channels, electric systems and transmission lines, and monitoring systems. New facilities for storage of radioactive waste and spent nuclear fuel are under design and planning, and they have been already assessed in other EIA's.

The INPP provides district heating to the town of Visaginas. New gas fired boilers have been constructed to provide heat to the city after the shutting down of INPP. Producing heat for district heating in Visaginas is an option under consideration in the NNPP project.

Decommissioning of INPP will continue for decades, and will thus be ongoing during construction and operation of the NNPP. New radioactive waste handling and storage facilities will be constructed as part of the decommissioning project. The aggregated impacts of these projects have been assessed in this EIA.

The existing municipal waste water treatment plant, operated by the state enterprise "Visagino energija", at present used by INPP, and which will be also used by the NNPP, require reconstruction. The reconstruction project was launched in 2008. A new

Visaginas waste water treatment plant (WWTP) will have the capacity of 5500 m^3/d, the treatment plant will be provided with activated biological sludge processing and will meet the current Lithuanian and EU requirements on wastewater management. The reconstruction project is funded by the State of Lithuania and the EU Cohesion Fund; it is expected the renovation will be completed by 2010. After the reconstruction the capacity and treatment efficiency of WWTP will be sufficient for the NNPP.

COMMUNICATION AND PARTICIPATION

One of the objectives of the EIA procedure is to increase availability of information of the proposed economic activity and improve the opportunities for citizens' participation.

The competent authority, the Lithuanian Ministry of Environment, is responsible for the coordination of the EIA procedure.

Different stakeholder groups were consulted when needed during the preparation of the EIA Report and the supporting reviews.

The EIA Report has been available for public display. The motivated (justified) proposals, that were received, were registered, evaluated and attached as appendixes to the approved EIA Report. Public information and discussion events were organized in the countries concerned.

The EIA relevant parties that review the EIA Report include the State Nuclear Power Safety Inspectorate, the Radiation Protection Centre, the Fire Protection and Rescue Department, Utena Public Health Service, Utena Region Environmental Protection Department, the Cultural Heritage Protection Department, Utena County Governor's administration, Administration of Visaginas Municipality, Administrations of Ignalina and Zarasai District Municipalities and the State Service for Protected Areas. The assessment has an important role in ensuring the quality of the EIA procedure.

Environmental impact assessment in a transboundary context is regulated by the Law on the Assessment of the Impact on the Environment of the Planned Economic Activities and by the United Nations Convention on Environmental Impact Assessment in a Transboundary Context (*Espoo Convention*). The Ministry of Environment is responsible for the practical organization of the environmental assessment procedures in a transboundary context. The Ministry of Environment has informed the respective authorities of Latvia, Estonia, Poland, Belarus, Finland, Sweden and Russia about the commenced environmental assessment process of the new nuclear power plant in Lithuania and inquired about their intent to take part in the environmental assessment procedure. Austria, Belarus, Estonia, Finland, Latvia and Sweden gave their comments on the environmental impact assessment of the new NPP. The comments have been taken into account in the preparation of the EIA Report and the supporting reviews.

Information about the EIA procedure is provided at "Visagino atomine elektrine" website – http://www.vae.lt. The website provides up-to-date information on the progress of the EIA procedure. The EIA Program and EIA Report are available in the Lithuanian, English and Russian languages, and the Summary of the EIA Report is available in German, Estonian, English, Finnish, Latvian, Polish, Russian and Swedish languages on the website.

ENVIRONMENTAL IMPACTS DURING THE CONSTRUCTION PHASE

The construction of the power plant will require a vast amount of workers in the area. It is estimated that up to 3 500 workers will be needed for the construction, while around 500 employees will be needed during the operational phase, depending on the technology chosen and the operation procedures. Foreign work force will be required during the construction phase.

The new labour force needed for the construction of the power plant will affect the economics and demography of the region. The NNPP region in Lithuania and Latvia will for 5-7 years have to host an exceptional amount of people. This will lead to a significant demand for goods and services and very significant positive socioeconomic impacts.

The construction works have to be accurately organized, since they will involve a large amount of labour force in the vicinity of the decommissioning project of INPP. Attention will have to be paid to the problems that the vicinity of these activities can create to each other in terms of traffic and congestions.

The first step of the works will involve excavation works, with the removal of up to 1.4 million cubic meters of excavated and blasted materials. Disposal areas will be required for this amount of soil. The construction works will increase the amount of traffic (especially cars and trucks) on the roads connecting Visaginas with the power plant construction site. It is estimated that 1 800 cars, 100 trucks and 60 buses will drive back and forth every day, producing emissions and noise. The traffic will however not have long term impacts on the air quality. Dust will also be generated, but will only affect the area of the construction site.

The waters of Lake Druksiai as well as groundwater will not be significantly affected by the construction of the NNPP because of implementation of an appropriate waste water system. Any direct discharge of untreated and polluting or hazardous material in the lake’s waters will be strictly forbidden. According to the provisions of the Lithuanian Regulation on Surface Water Management, entry of substances harmful to the water environment into the new NPP construction site or directly into the surface water management system with dust and precipitation, or due to the eligible activity exercised on the construction site is not considered such a disposal (e.g., operational emissions from technically fit vehicles and other machinery, dirt from tires, etc.).

Considerable amounts of waste will be produced during the construction phase of the new NPP. During the construction of the new NPP all possible and economically justified measures will be implemented to reduce waste amount, as well as to reduce detrimental impact on human health and the environment. Preventive measures to minimize waste generation will be employed, the amount of waste getting into dumps, as well as its harmfulness will be reduced, low-waste technologies will be introduced, and natural resources will be saved. In order to avoid the adverse effects on human health and the environment the requirements on waste prevention, accounting, collection, storage, transport, utilization, and disposal, set out in Law of the Republic of Lithuania on Waste Management and other legal acts, will be strictly adhered to.

The noise level during the construction years would increase, but the construction site is located in an uninhabited area.

There will be no radioactive releases during the construction phase.

ENVIRONMENTAL IMPACTS DURING THE OPERATIONAL PHASE

The state of waters

The new NPP will use water from Lake Druksiai for heat dissipation. The cooling water will be warmed up approximately ten degrees when passing trough the nuclear power plant in the case of direct heating, where the heated cooling water is discharged back to the lake. The quality of the cooling water will not change in any other way. Model computations of the impact of releases of warm cooling water to Lake Druksiai were carried out with a three dimensional hydrodynamic model. The effects of different NNPP thermal loads to the lake and different NNPP cooling water inlet and outlet locations on the water temperature of Lake Druksiai were investigated.

Based on modelling results and expert assessments it can be concluded that the ecologically acceptable thermal load to the lake will be approximately 3 160 $MW_{released}$. With this thermal load no significant impacts on the lake ecosystem are expected compared to the present state of the lake. With higher thermal load the impacts on the lake ecosystem start to be clear and significant.

However, with the present criterion for lake warming (maximum 20 % of the lake surface layer warming to over 28 degrees) the maximum allowable thermal load to the lake during the summer months is approximately 1 390 $MW_{released}$. Due to this additional thermal load reduction might be needed during the warmest month. Reducing the thermal load of 3 160 $MW_{released}$ to half during the warmest month would keep the lake temperatures below the present limit, possibly with few days of exception. Consequently the environmentally and economically best option may be to limit the thermal load to the lake mainly during the warmest months. There are several available technologies and their combinations. The environmentally and technically best cooling technology will be selected later in the design phase of the new plant.

The current outlet is the best alternative when the area warmed up is used as criteria. However, the different outlet options do not significantly differ from each other. The present NPP outlet position allows the cooling water to spread efficiently to the main part of the lake, allowing both cooling by heat exchange to atmosphere and mixing to cooler lake water.

The main hydrological impacts of the operation of the new NPP are the evaporative losses created when the heated cooling water will transfer the heat load to air by evaporation. According to water balance calculations the water resources will be adequate for the operation of the NNPP also during dry years.

During normal hydrological years the average lake level is not expected to fall below the normal and thus the hydrological effects on the lake and their ecological consequences are considered minor. During dry years the lake level would fall below normal, however staying above the minimum allowed regulation level (for approximately three successive dry years). Thus also the consequences of this kind of rare event can be estimated to be small.

Household and process waste water of the new NPP will be managed in accordance with the requirements of Lithuanian Regulation on Waste Water Management. The discharge of waste water into the environment may be performed only through a discharger, for installation whereof construction permission has been issued, and only after the approval of the conditions for waste water discharge in accordance with the set out procedures. The nutrient and other load from the NNPP will be small compared to the total load to Lake Druksiai coming from other sources. Surface water will be handled separately from household and process waste water; they will be managed according to the requirements of Lithuanian Regulation on Surface Water Management.

Climate and air quality

The operation of the new NPP will cause very limited emissions, mainly from the back up diesel engines and the traffic. These emissions will not have a significant detrimental impact on the ambient air quality of the Visaginas region, also taking the background contamination into account.

Geology, soil and groundwater

No significant impacts on geological conditions, soil or groundwater are expected during operation of the NNPP in either site alternative.

Biodiversity

Lake Druksiai and several other areas in the region are included in a European Union network of protected areas named “Natura 2000” and certain values of these areas are therefore to be preserved under specific regulations of the EU. The main focus of biodiversity impact assessment has been on the Lake Druksiai Natura 2000 –area. Lake Druksiai has been included in the Natura 2000 network based on both the EU Birds Directive and the Habitat Directive. The main focus has been on the possible water temperature change in the lake due to cooling water discharge, and the potential impacts of this on biodiversity values. Lake Druksiai can for ecological reasons not tolerate the planned maximum power generation. A maximum thermal load of approximately 3 160 $MW_{released}$ can be discharged to the lake without significant adverse impacts on essential biodiversity values of the lake, including the designation values for Lake Druksiai Natura 2000 area, being anticipated. Mitigation measures for biodiversity impacts are required.

Noise and the presence of workers, as well as direct construction measures destroying habitats will cause adverse impacts on other biodiversity values as well in both site alternatives. These impacts can however be mitigated to an acceptable level.

Landscape, land use and cultural heritage

The assessment of the landscape of the area shows how it already has been damaged by the construction and operation of the present power plant. The NNPP project would not cause further particular damages to the landscape. Photomontages showing possible impacts on the landscape from the most significant viewing points have been prepared and are provided in the EIA report.

No impact on cultural heritage values is expected in either site alternative.

Socio-economic environment

A significant positive impact on the socioeconomic environment of the NNPP region is expected. The new activity would reduce the adverse effects of the closure of the INPP, which would let the region without its main employment source. A need for a large workforce, in the order of up to 3 000–3 500 workers, will occur during the construction phase. This workforce will to a significant extent utilize the services of the region in both Lithuania and Latvia, which will bring significant positive socioeconomic impacts to the region. About 500 employees would work permanently in the NNPP.

A resident survey was performed in the area of the town of Visaginas and its surroundings as part of the EIA. The results show how the attitude of the great majority of inhabitants is favourable to the NNPP project.

Public health

The NNPP and the related traffic can have an adverse impact on air quality but the impact is so minor that it will not affect public health. The levels of noise in the vicinity of the NNPP will stay below allowable limits. The main positive impacts of the NNPP on public health are through the areas of improved economy and social security.

There will be no significant radiological impact on the population during the operation of the NNPP. Depending on reactor type, capacity and total number of units of the NNPP, annual doses of the critical group members of population due to releases of radioactive effluents (both airborne and liquid) into the environment vary in a range from 4.19 to 33.01 µSv (from 0.004 to 0.033 mSv). This is about 6 times below the dose constraint established for the protection of the health of members of the public, which is 200 µSv (0.2 mSv) per year.

In addition to the decommissioning activities at the Ignalina NPP existing nuclear facilities, the INPP decommissioning project foresees construction of:

- Interim Spent Nuclear Fuel Storage Facility (ISFSF);
- Solid Radioactive Waste Management and Storage Facility (SWMSF);
- Disposal Units for Very Low-level Radioactive Waste (Landfill repository);
- Low and Intermediate Level Radioactive Waste Near-Surface Repository.

Existing and planned nuclear facilities, located in the Ignalina NPP existing sanitary protection zone of 3 km radius are shown in Figure 4.

Figure 4. Existing and planned nuclear facilities, located in the INPP existing sanitary protection zone of 3 km radius.

Nuclear facilities indicated in Figure 4 are as follows:

1 – Building 158 (planned repository of bituminised RAW) and new interim storage facility for solidified radioactive waste (bld. 158/2); 2 – Reactor Units of the Ignalina NPP; 3A, 3B – Alternative sites for construction of new NPP; 4 – Existing SNF storage; 5 – New ISFSF; 6 – New SWMSF; 7 – Disposal units of the Landfill facility; 8 – Near-surface repository for low and intermediate level RAW; 9 – Buffer storage of the Landfill facility.

It is conservatively forecasted that in 2015 (when the new NPP is planned to be built at the earliest) the total annual effective dose to the critical group members of population due to airborne emissions and liquid discharges from the new NPP and existing and new nuclear facilities of Ignalina NPP at the boundary of the existing SPZ (with 3 km radius) will be about 0.05 mSv. The established dose constraint for members of the public is 0.2 mSv per year. Therefore, total annual dose in 2015 to population during normal operation of the facilities in the existing SPZ will, at a maximum, be about 4 times less than the dose constraint.

Based on experience from other countries and estimations about the impact of the NNPP on the public, the sanitary protection zone for the NNPP is suggested to be of 1 kilometre radius for all reactor types analysed in the EIAR. The proposed sites for the NNPP are within the existing INPP industrial site and sanitary protection zone. The shortest distance from the proposed sites to the boundary of the existing sanitary protection zone is about 1.5 km.

IMPACTS OF NUCLEAR FUEL PRODUCTION AND TRANSPORTATION

Uranium mining, processing and transportation will not be performed in Lithuania.

Production of nuclear fuel is also not planned in Lithuania. It is planned that nuclear fuel will only be transported. Fuel for the new power plant will be procured from the international nuclear fuel market and depending on country where it is procured, nuclear fuel will be transported by railway or overland routes.

Nuclear fuel would be transported to the NNPP in appropriate packages according to the national and international requirements.

WASTE

After the spent nuclear fuel is removed from the reactor core, it is stored in cooling ponds for a certain period of time needed the fuel to be cooled off, and then it can be moved into off-site facilities for further processing or storage. All NPP have spent nuclear fuel (SNF) ponds, associated with the operation of the reactor. The latest reactor designs incorporate ponds, capable to accommodate SNF produced during the period of 30 years. Later a new interim storage facility will need to be built, which will accept SNF from the reactor ponds of the new NPP. Radiological impact of such SNF storage facilities on the population and the environment is negligible. The environmental impact of the SNF storage facility of the new NPP will be assessed separately.

The SNF of the existing INPP, as well of the new NPP, stored at the interim storage facilities, will be further managed in accordance with the Radioactive Waste Management Strategy, approved by the resolution No. 860 of 3 September 2008 of the Government of the Republic of Lithuania. According to this Strategy there shall be analyzed possibilities to arrange a deep geological repository in Lithuania, a regional deep geological repository of several European Union member states and to transfer SNF to the states that own proper installations and assume responsibility for the SNF. If the global policy on SNF transfer to other states is not changed or new SNF reprocessing technologies do not occur, not earlier than in 2030 it will be started to consider, what location of Lithuania shall be used for construction of a deep geological repository. If needed, a possibility to elongate the SNF storage at the storage facilities for a period over 50 years will be analyzed.

The NNPP produces solid, liquid and gaseous radioactive waste, which have been studied in the EIA Report considering the different technological options. Radioactive releases during normal operation of the NPP and their impact on the environment will be lower than the limits set by the national and international legislation and the surrounding environment will not be significantly affected.

At the NNPP non-radioactive conventional and hazardous waste will be produced as well. They will be transferred to specialized waste handling companies. Waste prevention, recycling, reprocessing and other utilizations are envisaged as priorities.

CONCLUSION ON THE ENVIRONMENTAL AND SOCIAL FEASIBILITY OF THE PLANNED ACTIVITY

Utilization of Lake Druksiai for direct cooling is for ecological reasons only possible approximately up to a thermal load level of 3 160 $MW_{released}$. By combining direct cooling with wet cooling towers and/or dry or hybrid solutions the planned maximum power generation level of 3 400 MW_e is achievable from an environmental point of view.

It is conservatively forecasted that in 2015 (when the new NPP is planned to be built) the total annual effective dose to the critical group members of population due to airborne emissions and liquid discharges from the new NPP and existing and new nuclear facilities of Ignalina NPP during normal operation at the boundary of the existing SPZ (with 3 km radius) will be about 4 times less than the dose constraint.

Based on experience from other countries and estimations about the impact of the NNPP on the public, the sanitary protection zone for the NNPP is suggested to be of 1 kilometre radius for all reactor types analysed in the EIAR, well within the existing INPP sanitary protection zone.

Site No. 1 is slightly more preferable than Site No. 2 for the construction of the NNPP from an environmental point of view.

The environmental impact assessment did not find any environmental or social impacts of such significance caused by construction or operation of the NNPP that they could not be accepted or mitigated to an acceptable level. Thus the impacts from the construction, operation and decommissioning of all the Generation III/III+ NPP technologies considered for the NNPP would be acceptable at both sites considered.

The EIA does not take a position on the acceptability of a serious accident risk in terms of an individual point of view on ethical or other personal grounds. The assessment has aimed at presenting, as clearly as possible, the probability of a serious accident and comparison information regarding the related consequences so that the readers can use them as needed in the formation of their own opinion.

When handled properly, the spent fuel and other radioactive waste of the new nuclear power plant do not cause harmful impacts on the environment or people. The solutions for handling of these radioactive wastes will undergo their own environmental impact assessment procedures where the environmental feasibility of these solutions will be assessed.

MONITORING SYSTEMS

Environmental monitoring means the systematic observation of the state of the environment and its components and changes thereof and evaluation and prognosis of anthropogenic impact. The environmental monitoring system in Lithuania is comprised of state, local government and economic entity environmental monitoring in the course of the implementation whereof, information shall be accumulated and analyzed regarding the state of all of the natural environment elements, and their changes on a local, regional and state scale.

The state environmental monitoring is organized by the Ministry of Environment, and it is implemented by the Ministry of Environment or its authorized bodies, the Radiation Protection Centre or other state authorities.

The monitoring system for the new NPP will be designed to fulfil all the requirements of the Lithuanian legislation and regulations, the IAEA safety standards and obligations under the United Nations Conventions. A certain part of the existing INPP monitoring system can be integrated into the monitoring system of the new NPP. However, all the existing monitoring systems and devices applied will be modernized to meet the current requirements on preciseness and periodicity. During INPP operation, when implementing the environmental monitoring program a significant amount of data on the components of the environment have been accumulated. During the development of the new NPP environmental monitoring system the data aggregated during the performance of the INPP environmental monitoring and the results of the analysis (accumulated since the start of the operation, during operation and after decommissioning) will be employed.

The points of permanent surveillance of ambient air and precipitation, the sampling points of water, sediments, vegetation, water indicator organisms, and benthic animals of Lake Druksiai, layout of thermoluminescent dosimeters, the points of permanent surveillance of soil, pasture grass, drinking water, foodstuff, and plants are envisaged to be kept unaltered; however, measuring points of inlet and outlet water may change depending on the selected alternative of water inlet and outlet channels. Moreover, new groundwater monitoring boreholes, new dosimeters, etc. can be installed.

TRANSBOUNDARY IMPACTS

The transboundary impacts are mainly socioeconomic or linked to the impacts on Lake Druksiai. Radiological transboundary impacts will not occur during normal operation of the NNPP.

A significant positive impact on the socioeconomic environment in the foreign parts of the NNPP region is expected, mainly in Latvia through the need for workforce, accommodation and services. No significant negative socioeconomic impacts are expected as the NNPP will be constructed next to an existing NPP, to which the surrounding areas have adjusted.

Evaporation of water by cooling the NNPP would reduce the overall volume of water in Lake Druksiai, thereby impacting the quantity of water discharged to River Prorva. The decrease of mean flow would impact the approximately 50 km long stretch of River Prorva before the confluence of River Dysna. The minimum allowable discharge in River Prorva will remain at the present level (0.64 m^3/s) in all of the cooling scenarios.

No significant transboundary impacts on terrestrial and semi-aquatic fauna, flora and biodiversity are expected.

NUCLEAR SAFETY AND RISK ANALYSIS

High safety culture and special safety principles and regulations are required in the design and operation of nuclear power plants. The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation. All the most relevant principles of nuclear safety are clearly presented in the EIA Report, together with all the well-established procedures able to minimize any risk of accident. The use of nuclear power in Lithuania requires a license and it is regulated by law. The authorities involved in the safety of the nuclear installations in Lithuania are the State Nuclear Power Safety Inspectorate (VATESI), the Ministry of Health (via the Radiation Protection Centre), the Ministry of the Economy, the Ministry of Environment and the Ministry of Internal Affairs.

A risk analysis of potential accidents resulting from the proposed economic activity has been done according to the recommendations of normative document “Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity” as part of the EIA. Accidental releases from the NNPP and their impacts on the environment and public have been considered for two scenarios: design basis accident (DBA) and severe accident. Loss-of-coolant accident has been chosen as the DBA to be assessed since it envelopes the consequences of all DBA's. For the severe accident case the release of 100 TBq Cs-137 into the environment has been estimated and possible impacts and protection actions for population in case of such severe accidents are described.

The dispersion of accidental releases in these situations has been simulated with Air Quality and Emergency Modelling System SILAM of the Finnish Meteorological Institute (FMI). The approach applied is based on brute-force multi-scale computations of dispersion using actual meteorological data from weather archives. To cover all realistic meteorological conditions several cases in different meteorological conditions during the years 2001 and 2002 have been simulated.

The assessment of doses received by the public as a result of accidental releases is based on the results of the dispersion simulations and it utilizes empirical coefficients and methodologies for converting the modelled concentrations in air and depositions to doses. The exposure of the environment and people depends on the specific meteorological conditions during the accident and the geographical location of the receiving point and thus the results of the study are given as 2-dimensional maps of the exposure levels, which are not exceeded with a certain probability for any realistic meteorological conditions.

The results of the dispersion modelling and dose estimation have shown that the dose for the members of public caused by the Loss-of-coolant accident is less than 10 mSv as required by the Lithuanian Regulation. Sheltering is not necessary in Lithuania or abroad in case of either Loss-of-Coolant accident or Severe accident, neither is evacuation, temporary relocation or permanent resettlement. The main protective actions in case of a Severe accident are iodine prophylaxis and restrictions on the use of foodstuffs, milk and drinking water. Some mostly short time restrictions of certain foodstuff will be needed in case of both severe accident and Loss-of-coolant accident.

To mitigate the consequences of an accident to the public, the power plant and rescue service authorities maintain emergency preparedness. The Lithuanian nuclear energy legislation sets requirements for civil defence, rescue and emergency response actions.

IMPACTS OF DECOMMISSIONING

The NNPP decommissioning involves the implementation of legal, organizational, and technical measures of the NNPP management, when a decision is taken not to use it anymore for its intended purpose. The NNPP management refers to exercise of the NNPP decontamination, dismantling, the management of decommissioning residues and waste, the site clean-up and other steps in order to achieve not restricted use of the site or a permission to construct other nuclear facilities on the site.

The decommissioning phase is a long and expensive process that will generate both ordinary and radioactive waste. A relevant amount of resources and time can be saved designing a reactor with the coming decommissioning project in mind. Moreover, the fact that this phase will not occur before the end of the life cycle of the plant (around 60 years of operation) gives time to the power plant operators to gather the resources needed for the implementation of this phase.

Decommissioning of the NNPP will undergo appropriate environmental impact assessment in due time.

1 GENERAL INFORMATION

“Lietuvos Energija AB” initiated the environmental impact assessment (EIA) procedure concerning a new nuclear power plant (NNPP) in Lithuania. After the amendments of the Law of the Republic of Lithuania on the Nuclear Power Plant had been adopted and the Joint Stock Company “Visagino atomine elektrine, UAB” had been established, the later took over all the preparatory works including the EIA procedure of NNPP. The power plant would be located in the near vicinity of the current Ignalina nuclear power plant (INPP), in the municipality of Visaginas on the shore of Lake Druksiai in north-eastern Lithuania (Figure 1.1-1). The net electrical output of the new nuclear power plant (NNPP) would be at most 3 400 MW_e and it would replace the current INPP Unit 1, which was closed on December 31, 2004 and Unit 2, which is scheduled to be shut down at the end of 2009.

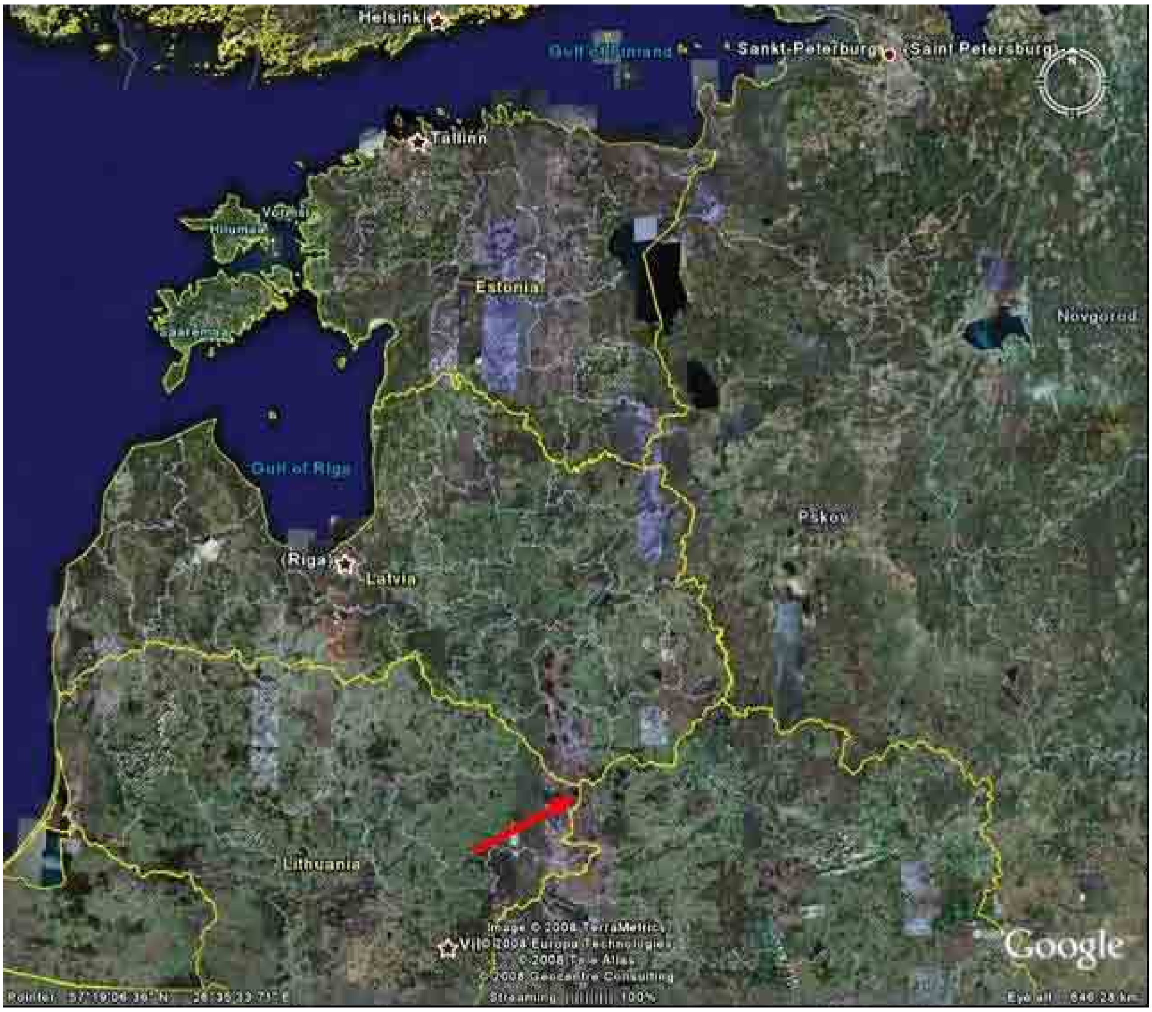

Figure 1.1-1. Location of the NNPP project area.

Lithuania has no primary energy sources of its own. From the late 1980s, the Ignalina nuclear power plant (INPP) has produced a large percentage of Lithuania’s electricity. The Lithuanian electricity and gas networks are closely interrelated to the north-west power sectors of the Russian Federation.

The meeting of the finance ministers from the group of seven industrialized nations of the world in Munich in 1992 was crucial to Lithuania and operation at INPP. The political decision was made that its RBMK reactors should be closed, as the reactors were judged incapable of being upgraded to western safety levels.

Presently the INPP is the only nuclear power plant in Lithuania. About 70 % of the total domestic electricity production was generated by the INPP in 2005. The current Lithuanian electricity generating capacities, including small capacity combined heat and power plants that are planned to be constructed, will be sufficient to meet the national demand until 2013. After the shutdown of INPP Unit 2 the new nuclear power plant would become the major electricity generating source in Lithuania.

Before the start of the EIA procedure for the new NPP, in order to highlight the influence of different factors on the competitiveness of the new NPP and to assess the possibilities of nuclear energy use continuity in Lithuania, as well as the political, social, economic and environmental assumptions in the context of electricity prices, supply reliability, security, and macroeconomic development, in 2004-2005 the following studies were developed:

- J. Gylys et al. Scientific research “Study of Nuclear Energy Use Continuity in Lithuania, 2004”;
- R. Deksnys “Analysis of Nuclear Power Plant Competitiveness in the Energy Markets of the Baltic, Scandinavian, West European countries and Russia, 2005”.

Later on, in 2006 the three Baltic countries' energy companies “Lietuvos Energija AB”, “Latvenergo AS” and “Eesti Energija AS” additionally conducted a feasibility study of the new NPP in Lithuania. Among other issues the study analyzed the conditions to build a reactor of proper type. The working group of technologies and environmental issues is responsible for assessment of the best available technologies for the nuclear plant, forecasting power, investment and operating costs for the potential reactor. In the study the group carried out a thorough assessment (although preliminary) of the reactors currently proposed in the market. Market research, carried out in the report of the feasibility study, confirmed that all these reactors assure the highest safety standards in line with the safety standards of other nuclear reactors currently operated in Europe and in the world. It was noted that there is a sufficient number of suppliers of such reactors, which provides a competitive environment in the technology procurement phase.

The planned new NPP meets the aims of the National Energy Strategy (*State Journal, 2007, No. 11-430*) as well. According to the strategy, one of the identified main tasks is “to ensure the continuity and development of safe nuclear energy; to put into operation a new regional nuclear power plant not later than by 2015 in order to satisfy the needs of the Baltic countries and the region”.

According to the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity (*State Journal, 2005, No. 84-3105*) construction, shutdown or decommissioning of nuclear power plants or other nuclear facilities are such economic activities for which an environmental impact assessment (EIA) procedure must be carried out. The objectives of the EIA procedure are defined in Article 4 of the named law and shall be as follows:

- to identify, characterize and assess potential direct and indirect impacts of the proposed economic activity on human beings, fauna and flora; soil, surface and entrails of the earth; air, water, climate, landscape and biodiversity; material assets and the immovable cultural heritage, and interaction among these factors;
- to reduce or avoid negative impacts of the proposed economic activity on human beings and other components of the environment, referred to in paragraph above;
- to determine, if the proposed economic activity, by virtue of its nature and environmental impacts, may be allowed to be carried out in the chosen site.

The objective of this particular EIA of the planned new NPP is to fulfil the legal requirements by assessing if the impacts from the construction, operation and decommissioning of the Generation III/III+ NPP technologies considered for the NNPP would be acceptable at the two sites considered.

The content and structure of this EIA Report meet the requirements of the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity (*State Journal, 2005, No. 84-3105*) and consider the requirements of the Regulations on Preparation of Environmental Impact Assessment Program and Report (*State Journal, 2006, No. 6-225*).

1.1 ORGANIZER OF THE PROPOSED ECONOMIC ACTIVITY

The organizer of the proposed economic activity is Visagino atomine elektrine, UAB, which was founded during the EIA process, and took over the project implementation responsibility from Lietuvos Energija AB.

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1.2 DEVELOPERS OF THE EIA REPORT

The developer of the EIA Report is Consortium Pöyry Energy Oy (Finland) and Lithuanian Energy Institute (Lithuania). Pöyry Energy Oy is the leader of the Consortium.

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1.3 NAME AND CONCEPT OF THE PROPOSED ECONOMIC ACTIVITY

The proposed economic activity is named as the “New Nuclear Power Plant in Lithuania”.

By this proposed economic activity a new nuclear power plant will be constructed and operated in the vicinity of the existing Ignalina NPP. Total capacity of electricity production of the new NPP will not exceed 3 400 MW.

The new nuclear power plant will consist of two to five units. In some parts of this assessment the impacts are assessed for one or two reactors of about the size of 1 600-1 700 MW. In these cases the impacts of three to five units with smaller reactor size are assumed to be the same as for the two units with greater reactor size.

In the new NPP, electricity will be generated in accordance with the principles and regulations concerning the internal energy market of the European Union (EU). In accordance with sustainable development, the EU aims to reduce harmful environmental impacts of energy production and use. Another objective is to increase the EU's competitiveness, which requires investments in the energy production and transmission capacity. It is estimated that investments of EUR 900 billion in new electricity generation capacity will be needed in the EU area during the next 20 years. To secure the reliability of energy supply, the EU focuses particular attention on curbing the increase of the need for importing oil and natural gas. (*European Commission, 2007*)

Lithuania needs new carbon dioxide emission-free electricity production capacity to meet the challenges posed by climate change, competitiveness and reliability of operation, and to ensure economic growth and the Lithuanians' standard of living. The objective is to reduce the dependence on fossil fuels. The measures proposed by the European Commission in January 2008 with a view to curb climate change require that carbon dioxide emissions will be reduced by 20 % from the 1990 level in the EU area by 2020. The long-term target is to cut carbon dioxide emissions by 60–80 % in the developed countries by 2050. (*European Commission, 2008*)

1.4 STAGES OF ACTIVITY AND SCHEDULES

The proposed economic activity can be divided into three main stages making impacts on the environment:

1. Construction and commissioning;
2. Operation;
3. Decommissioning.

Before the start of these stages of the proposed economic activity, licenses and permits for the implementation of corresponding activities shall be obtained from the public administrations and regulatory bodies (VATESI, the Ministry of Environment, the Radiation Protection Centre, etc.). Licenses and permits are issued under the procedures set out in the Law on Nuclear Energy (*State Journal, 1996, No. 119-2771*) and the Regulations of Licensing of Activity in Nuclear Power Industry (*State Journal, 1998, No. 12-274*). Since licensing and permit issuance do not cause any environmental impact, in the EIA Report these issues are not examined in detail. The authorization process of a new NPP in Lithuania is shown in Figure 1.4-1.

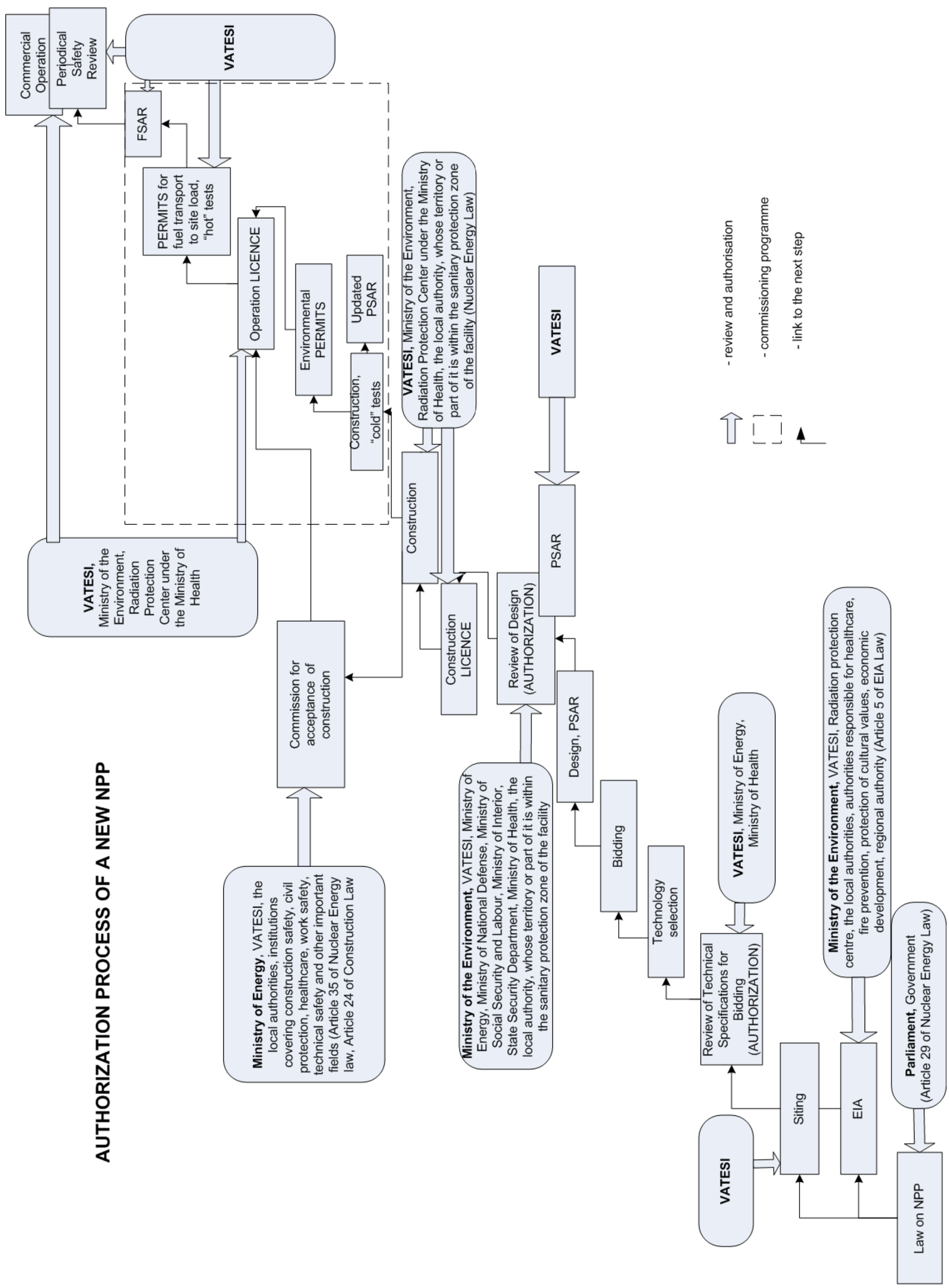

Figure 1.4-1. The authorization process of a new NPP in Lithuania.

It is planned that at least the first unit of the new nuclear power plant is in operation not later than 2015. Typical construction time of a new NPP unit is 5–7 years (Figure 1.4-2). Operation time is approximately 60 years or even more. Decommissioning time depends on the decommissioning strategy and can last from 20 to 100 years.

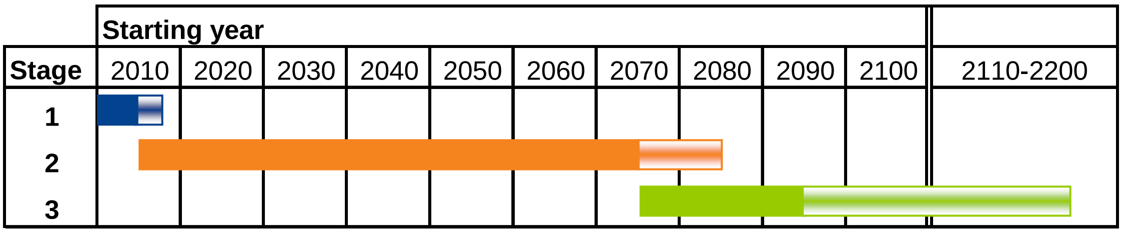

Figure 1.4-2. The estimated durations of the three main stages of the NPP project in case of one reactor.

In case of two or more reactors, it is assumed that construction work for the reactors would start two years after the previous one. In case of two reactors this would mean two years delay in all the different stages of the project.

The construction and commissioning stage of a reactor can be further divided into three stages: design adaptation and site preparation, actual construction time and start-up tests. Depending on the chosen reactor type, the durations of these stages vary so that total duration of the construction and commissioning is about 5–7 years (Figure 1.4-3).

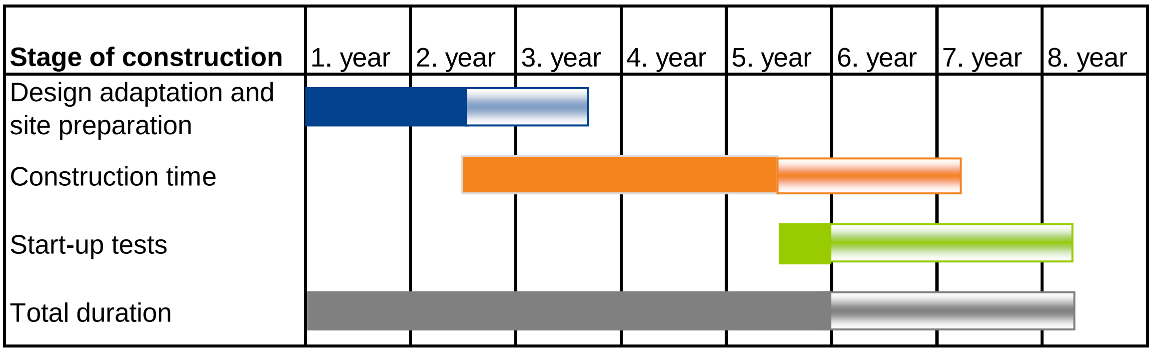

Figure 1.4-3. The durations of the different stages of the construction and commissioning of the new NPP.

1.5 ENERGY PRODUCTION

Information on planned production of energy is presented in Table 1.5–1.

Table 1.5–1. Energy production.

Energy type	Planned annual amount (output 1700 MW)	Planned annual amount (output 3400 MW)
Electrical energy, TWh/year	13	26
Thermal energy, TWh/year	0.4*	0.7*

* If heat for district heating of Visaginas will be produced.

1.6 DEMAND FOR RESOURCES AND MATERIAL

Demand for resources and materials during construction and operation of the new NPP is summarised in Table 1.6–1, Table 1.6–2, Table 1.6–3 and Table 1.6–4.

The estimations about the maximum consumption of main raw materials during the construction of the new NPP are presented in Table 1.6–1. These estimations are for the reactor types of the biggest size, for example EPR.

Table 1.6–1. Information about consumption of raw materials during construction of the new NPP (amounts are for 2 units 1700 MW each).

Material	Quantity
Earthworks (excavation)	1 400 000 m^3
Earthworks (fill materials)	1 300 000 m^3
Concrete; reinforced	640 000 m^3
Concrete; infill	60 000 m^3
Liner (skin and sleeves)	1 800 t
Turbine building (metal structures)	10 000 t + 46 000 m^2 metal cladding
Pools (Inox)	600 t
Steel reinforcement	90 500 t
Pre-stressing	3 970 t

Estimations on the fuel and energy consumption during the operation of the new nuclear power plant are presented in Table 1.6–2. The consumption of nuclear fuel will depend on the chosen reactor type.

Table 1.6–2. Information about fuel and energy consumption during operation of the new NPP.

Energy and technological resources	Measurement unit	Annual consumption amount (1 reactor)	Annual consumption amount (2 reactors)	Source
House load	MW	100	200	NNPP
Natural gas (if used for both reserve heat boilers and back-up power engines)	m^3	156 000	312 000	Lietuvos Dujos AB
Diesel fuel (if used for both reserve heat boilers and back-up power engines)	l	143 000	286 000	Fuel providers
Nuclear fuel for PWR and BWR reactors (3–5% enriched Uranium Dioxide UO_2)	t	29	58	Not defined yet
Nuclear fuel for PHWR (natural or low enriched Uranium Dioxide UO_2)	t	102	204	Not defined yet

Table 1.6–3 presents information about chemical substances and preparations containing dissolvents that are possibly used during the operation of the new nuclear power plant. Boric acid is used in the primary coolant of EPR reactors. It can possibly also be used in some support systems at the used fuel storage areas. Hydrazine is used in the component intermediate cooling system for deoxidization and corrosion prevention. Ammonia is used in the feed water system to control the pH value of the water. Lithium hydroxide is used in the primary circuit to control the pH value. Sulphuric acid (H_2SO_4) is used in demineralization as a recovery chemical of the ion exchangers. Sodium hydroxide is used as different solutions. It is used in the demineralization as a recovery chemical of the ion exchangers and in the feed water system to control the pH value of the water. Some lubricating oil will also be used.

Table 1.6–3. Information about chemical substances and preparations containing dissolvents possibly used during operation of the new NPP.

Name of the chemical substance and preparation containing dissolvents	Annual amount (1 reactor)	Annual amount (2 reactors)	Classification and labelling of the chemical substance or preparation [1]		
			Category	Hazard reference	Risk phrases
Boric acid	8 000 kg	16 000 kg	Xi	Irritant	R36/37/38
Hydrazine	22 m^3	44 m^3	R10; Carc. Cat. (2)	Flammable; Carcinogenic	R45 T; R23/24/25 C; R34 R43 N; R50-53
Ammonia	1 200 l	2 400 l	R10; T	Flammable; Toxic	R23 C; R34 N; R50
Lithium hydroxide	40 kg	80 kg	T	Toxic	R22 R23 R34
H_2SO_4	11 000 kg	22 000 kg	C	Corrosive	R35
NaOH (50 %)	3 200 kg	6 400 kg	C	Corrosive	R35
NaOH (10 %)	*dilution*	*dilution*	C	Corrosive	R35
NaOH (30 %)	*dilution*	*dilution*	C	Corrosive	R35
Lubricating oil (Addinol CLP 460 S)	0.5 m^3	1 m^3	T; Xn; Xi; N	Toxic; Harmful; Irritant; Dangerous for the environment	R22 R23 R24 R34 R38 R41 R43 R48 R50 R51 R53

Comment: 1 – According to the Law on Chemical Substances and Preparations (*State Journal, 2000, No. 36-987*) and Order of Classification and Labelling of Dangerous Chemical Substances and Preparations (*State Journal, 2001, No. 16-509; 2002, No. 81-3501*)

All the chemicals at the site will be handled and stored in appropriate manner to minimize the risk of environmental impact (Table 1.6–4).

Table 1.6–4. Storage of chemical substances and preparations containing dissolvents.

Name of the raw material, chemical substance or preparation	Amount for storage at site (1 reactor)	Amount for storage at site (2 reactors)	Storage manner [1]
Boric acid (in EPR)	10 t	20 t	Chemical storage facility, stored in separate tanks in containment basin
Hydrazine	17 t	30 t	
Ammonium	2 000 l	4 000 l	
Lithium hydroxide	0.01 t	0.02 t	Chemical storage facility, stored in purchase package
H_2SO_4	2 m^3	4 m^3	Chemical storage facility, stored in separate tanks in containment basin
NaOH (50 %)	2 m^3	4 m^3	
NaOH (10 %)	0.5 m^3	1 m^3	
NaOH (30 %)	0.2 m^3	1 m^3	
Lubricating oil	140 m^3	280 m^3	Stored in separate tank in containment basin

Comment: 1 – Underground reservoirs, tanks, structures, fuel storage areas covered with concrete for minimization of risk to environmental impact

1.7 SITE STATUS AND TERRITORY PLANNING DOCUMENTS

The considered sites for the new NPP (see Figure 1.7-1) are within an industrial land area allocated for State Enterprise Ignalina NPP (land parcel No. 4535/0002:5 and No. 4535/0003:2) (*Utena region governor order No. 14-293, dated June 20, 2003, On permission of State land usage at Ignalina region*). In accordance with land usage specialty (*State land usage specialty No. PN 45/03-0071 and No. PN 45/03-0072, Ignalina, July 2, 2003*) State Enterprise Ignalina NPP is allowed to use the site for unlimited time period.

The land usage purpose is defined as “of other special purpose (production and distribution of electric energy, operation of nuclear power units, nuclear fuel storage, supervision and maintenance of energy installations and other)”. Due to the proposed economic activity the land usage will not need to be changed. The special land usage conditions will be considered also.

On December 12, 2006 Director of Visaginas municipality administration by the order No. IV-652 “Concerning to approval of detailed plan” has approved the new revision of a detailed plan for the land parcel No. 4535/0002:5, which was prepared by UAB “Urbanistika” and coordinated by the State Enterprise Ignalina NPP. The main goal was to optimize land usage. The changes in the new revision of the detailed plan will not affect the status of the proposed sites for the new NPP.

The proposed sites for the new NPP are within the existing INPP industrial site. A 3 km radius sanitary protection zone (SPZ) is defined for Ignalina NPP site. There is no permanently living population within the existing sanitary protection zone and the economic activity is limited as well. The proposed economical activity is distant from residential areas. The sanitary protection zone for the new NPP is proposed in Section 7.10.2 of this EIA Report.

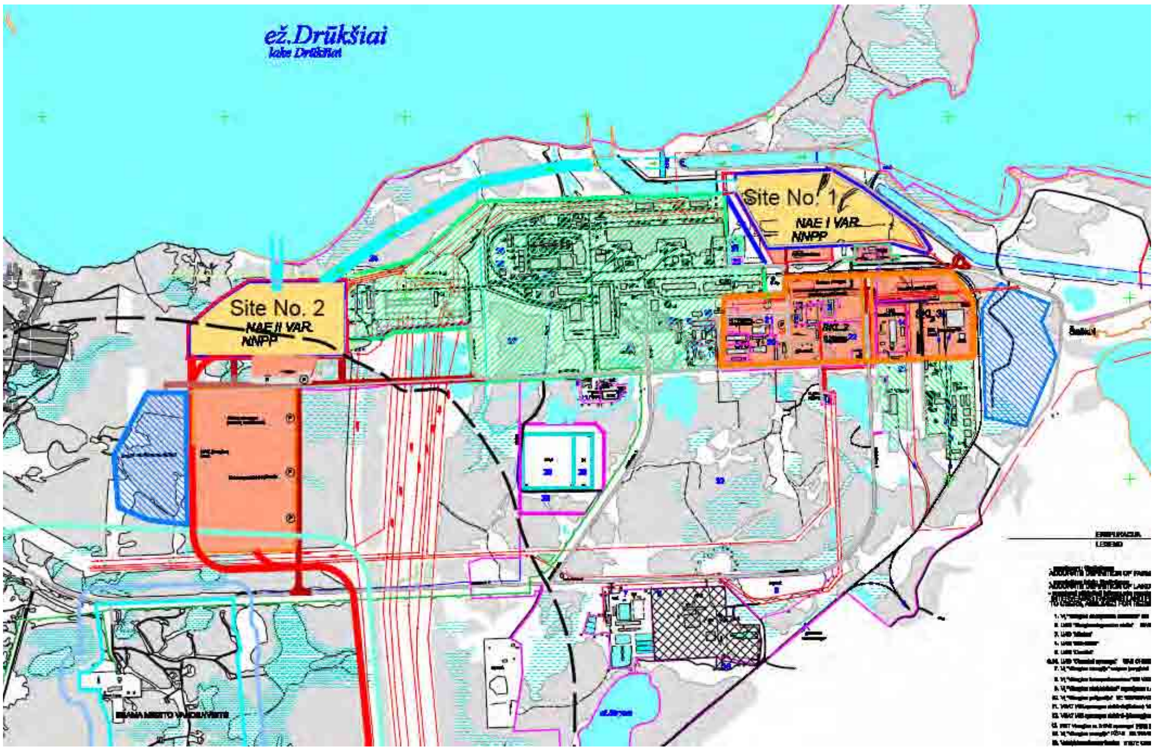

Figure 1.7-1. The proposed sites for the new NPP.

Alternative site 1 (see Figure 1.7-1 and Figure 1.7-2) is situated east of Unit 2 of the present power plant and comprises the area, which was previously planned for Units 3 and 4. The site area is approximately 0.493 km^2 and ends at its northern side (length 0.6 km) directly at the cooling water discharge channel common for existing Ignalina NPP Units 1 and 2. South of Units 1 and 2 the area is limited by the road from west to east. The eastern part of this area is triangular shape due to the existing railways at its eastern border from north-west to south-east. At this eastern border there are digs filled with water, which are the partially constructed new cooling water channels for the previously planned Unit 4. The length of the western border is approximately 0.58 km. The perimeter of this site is approximately 3.5 km. At its southern border (length of 1.255 km) the interim spent nuclear fuel storage facility for Units 1 and 2 (buildings 192, 193 and 194) is located. Also a buffer storage facility for very low level waste (VLLW) and a free release facility for the existing INPP are planned to be built at the southern border of alternative site 1. Construction of the free release building and security fence surrounding all the above mentioned objects has already started.

Figure 1.7-2. A view of alternative site 1 (east of current unit 2).

Alternative site 2 (see Figure 1.7-1 and Figure 1.7-3) is situated in an area west of the existing switchyard and is currently an unbuilt area (swamp, bushes). Its size is approximately 0.424 km^2. Its northern border is the shoreline of Lake Druksiai (length approximately 0.75 km). The other three borders are straight, forming a rectangular area, the eastern side of which is 1.1 km and the western 0.66 km long. The existing Building No. 108 (administrative building of State Enterprise “Visagino Energetikos Remontas“) is in the area. Better road connection and new railway connection have to be built to the site.

Figure 1.7-3. A view of alternative site 2 (west of the existing switchyard).

Present status of territorial planning documents in the area is as follows:

- Lithuanian territory general plan. The analyses of Lithuanian territory general plan and NNPP territory planning correlation issues have been made. Therefore, on the 7th of May in 2008 the Government of the Republic of Lithuania approved the resolution on addition of Lithuanian territory general plan's measures implementation plan concerning NNPP preparatory works.
- Utena county plan. It has been agreed and approved that the NNPP will be included in the Utena county plan. It is planned that Utena county plan, after presentation to the public, will be presented to the Government for approval by the end of the first half-year of 2009.
- Visaginas, Zarasai and Ignalina municipalities plan. It has been agreed and approved (by the Visaginas municipality common council decision) that the NNPP will be included in the Visaginas, Zarasai and Ignalina municipalities plan. It is planned that this municipalities plan will be prepared, presented for the public and approved by the end of 2009.
- NNPP detailed plan. The legal analyses of all sites, which may be needed for a NNPP construction, are under preparation. After analyses are ready, the changes and amendments of legal acts will be done and detailed planning will be initiated. It is estimated that the NNPP detailed plan preparation procedures will be completed in 2009.

1.8 UTILIZATION OF THE EXISTING INFRASTRUCTURE

After the present Ignalina NPP will be closed, some of the existing infrastructure in the area will be available for the new NPP. The possibilities to reuse parts of the existing infrastructure and equipment have to be examined as to its age, integration possibilities, interfacing of old and new infrastructure, requalification requirements, economic savings and various other aspects to assure the right selection. In this Section a preliminary evaluation of the existing infrastructure, which probably may be integrated into the new NPP, is presented. A more detailed examination will be done during the design stage of the new NPP. Since the compatibility of the existing infrastructure and equipment with the new NPP systems and the management of interfacing old and new infrastructure are some of the key issues to be examined, the supplier of the new NPP has to approve the integration of some of the existing infrastructure.

1.8.1 Hydraulic structures of Lake Druksiai

1.8.1.1 Regulation of the level of water

The level of water in Lake Druksiai is regulated to its present level. It is assumed that this regulation will continue also during the operation of the new NPP.

A blind earth dam was built in 1953 at the place of junction of the Apyvarde River to close the channel and the flood plain of the Druksa (called Drisvyata in Belarus) River (see Fig. 7.1-3 in Section 7.1). This dam secures the flow from the Apvardai Lake trough the Apyvarde River into Lake Druksiai. The crest and the slopes of the earth dam are lined with concrete on the side of the Apyvarde River and the slope is additionally strengthened with reinforced concrete plates. Also on the other side of the dam slope an additional embankment has been constructed. (*Ignalina Nuclear Power Plant, 2003*)

Also in 1953 a run-off regulation sluice, called “Object 500”, was built on the River Prorva to regulate the level of Lake Druksiai. Downstream from this a hydroelectric power plant (HPP), called “Tautu Draugyste”, was built between the Lakes Stavokas and Abaliai (Obole in Belarus). The HPP building and the water intake openings are combined in one concrete block. The concrete block has three openings, two for turbine operation and a third one for discharge of excess water. Both Object 500 and the HPP are located in the area of the Republic of Belarus.

The HPP was taken out of operation in 1982 and the turbines have been disassembled. However, the level of Lake Druksiai is still regulated by the gates of the HPP. The Object 500 currently functions as a transit structure of water flow from Lake Druksiai to the hydraulic structure of former HPP. The radial gates of it are currently lifted to the maximum to secure full discharge. The water from Lake Druksiai flows into Lake Stavokas where from the water is discharged via the stop logs of the water regulating hydraulic structure based on the former HPP.

Under an agreement (signed on February 6th, 1995) concerning Object 500 and HPP “Tautu Draugyste” between the Governments of the Republic of Lithuania and the Republic of Belarus, responsibility for Object 500 has been transferred to the Republic of Lithuania, whereas any agreement concerning the proprietary rights of the HPP has not been signed till now.

In case the HPP and the earth dam of the diversion channel of the HPP are damaged for some reason, the level of the Lake Druksiai can be regulated with the Object 500.

The state of the present hydraulic structures will be considered during the preparation of corresponding technical specifications and designs. In case of necessity the control of these structures can be updated, the structure can be renovated or other works can be carried out in order to regulate the water level of Lake Druksiai, as it has been done up to know, during the operation of the existing INPP.

1.8.1.2 Cooling water channels

The shape of the Lake Druksiai shore with its peninsula leads to an ideal arrangement for the cooling water inlet and outlet of the existing INPP. Lake Druksiai has the biggest depth close to the shore at the site of the water inlet. The water inlet is located at 6.6 meters depth (near the bottom) and is designed as an open channel with embankments in the lake part. From the power plant the water is let out through a closed reinforced concrete channel that then goes into an open channel. The channels are conjugated by a siphon structure.

The cooling water inlet and outlet were designed for four units, of which the two first units were realized. The channels are already partially excavated for the remaining, but not realised units. The outlet channel is designed for a maximum discharge of 170 m^3/s with 4 m filling level (*Ignalina Nuclear Power Plant, 2003*).

Cooling water inlet and outlet channels of the present INPP may be reused after renovation especially for alternative site 1 of the NNPP. The inlet channel would have to be somewhat extended. The maximum discharge from the new NPP would be 160 m^3/s. The distance from site 2 of the new NPP might be too long for the existing cooling water inlet channel to be used.

The renovation work can be carried out only after INPP Unit 2 is totally defueled (i.e. in 2015). Modifications for avoiding crossing of old and new intake and outlet connections will have to be studied in detail during the design stage of the NNPP.

1.8.2 Water supply

Potable water is used for household and process water purposes in the new NPP. Potable water supply for the present INPP is outsourced to the State Enterprise "Visagino Energija", which also serves the town of Visaginas. Ground water is used as the source of raw water and it requires only a simple treatment of aeration and filtration to remove excessive iron. The total water production capacity is 31 000 m^3/d, but as one of the INPP units has already been closed and a drastic water consumption reduction has taken place in Visaginas, the present capacity in use is only about 10 000 m^3/d, and the daily average output is about 6 900 m^3/d. The treated water storage tanks have a capacity of 12 000 m^3, which provides for adequate stand-by supply volume. Continuous supply to the INPP is secured with a 500 kVA stand-by diesel generator. The plant instrumentation and automation will be upgraded in a project started in May 2008.

The maximum potable water demand of the new NPP is 1300 m^3/d (for more detail, see Section 7.1). "Visagino Energija", or its municipal successor, will thus have adequate capacity to supply all the needed potable water for the new NPP.

Some of the potable water needs to be demineralised before it is used as process water. The inactive part of the existing demineralised water system of the INPP has a maximum capacity of 1080 m^3/d. The need for demineralised process water for the new NPP will be maximum 1000 m^3/d. Thus the existing system may be reused for the purposes of the new NPP.

1.8.3 Waste water treatment

"Visagino Energija" operates also the municipal wastewater treatment plant of the region. The non-radioactive wastewater of the INPP is lead to this plant to be treated. The plant has a capacity of 21 000 m^3/d, but it is in need of rehabilitation. A reconstruction project has been planned and its implementation was started in May 2008 by signing the construction contract. The new plant will have a capacity of 5 500 m^3/d. It will be based on an activated sludge biological process. The new plant will be able to meet the current Lithuanian and EU effluent standards. After the rehabilitation project has been finalized, the existing municipal wastewater treatment plant can be used to serve the new NPP. The present wastewater flow from the town of Visaginas is about 4 000 m^3/d and is decreasing. The new NPP will need a maximum of 600 m^3/d of household wastewater treatment capacity. The maximum capacity is needed during the construction stage of the NNPP. During normal operation the needed capacity will be about half of this (i.e. 300 m^3/d, see Section 7.1).

INPP surface water consists of precipitation and irrigation water getting onto the surface of the urbanized areas, collected from the uncontrolled areas (roads, car parks, etc.), the building roof drainage systems and other sources, not contaminated with radionuclides. Surface water contains particles and can also be contaminated with hydrocarbons. The INPP surface water run-off system is equipped with grease/oil separators (*Ignalina NPP Decommissioning Service, 2007*). The possibilities to use the INPP site surface water drainage in the new NPP surface water management system will be examined during the technical design. Measures will also be provided assuring that during the NNPP construction the surface water management systems of both the existing INPP and of the future near surface radioactive waste repository at Stabatiskes site would not be damaged.

1.8.4 Waste management

The provisions and tasks of the new version of the National Strategic Waste Management Plan (*State Journal, 2007, No. 122-5003*) have been formulated on the basis of a thorough analysis of the current waste management state. For 2007–2013 waste prevention, recycling, reprocessing and other utilizations have been envisaged as priorities. These priorities are binding as to the minimal production of waste at the new NPP to be achieved. The waste that can not be avoided shall be processed or otherwise utilized to minimize its disposal in landfills. During the construction and operation of the new NPP all possible and economically justified measures will be implemented to decrease waste amount, as well as to reduce detrimental impact on human health and the environment. Preventive measures to minimize waste generation will be employed, the amount of waste getting into dumps, as well as its harmfulness will be reduced, low-waste technologies will be introduced, and natural resources will be saved (see Chapter 6).

Within the frame of INPP decommissioning a new solid radioactive waste management and storage facility (SWMSF) has been contracted and its commissioning is scheduled for 2010 (*NUKEM Technologies GmbH and LEI, 2008*). Treatment of the INPP operational radioactive waste is expected to last until 2020. After 2020, and up to the end of the solid waste treatment facility’s (SWTF) 30 years design life, the facility will be used to process INPP decommissioning waste. Technically a simultaneous treatment of both the INPP decommissioning waste and the NNPP operational waste could be viable. The design lifetime of the new solid waste storage facilities (SWSF) for short-lived and long-lived radioactive waste will be 50 years (until 2060). A new project for construction and commissioning of near surface repository (NSR) for short-lived low and intermediate level (LILW-SL) radioactive waste is underway. The site of the NSR has been confirmed at Stabatiskes, in the vicinity of the INPP (*Resolution No. 1227 of the Government of the Republic of Lithuania, dated November 21, 2007*). When NSR will be commissioned and storage/disposal containers with LILW-SL from SWSF are transferred to the NSR, the containers with LILW-SL from NNPP can be temporary stored at SWSF until 2060. The more detail analysis of possibilities to reuse existing treatment and storage facilities for NNPP radioactive waste management will be performed during the predesign studies.

The existing INPP liquid radioactive waste treatment facility is inappropriate for the new NPP and it will not be used. The new NPP will have its own liquid radioactive waste treatment installations. At Ignalina NPP the Cement Solidification Facility for liquid radioactive waste solidification has been commissioned. During the predesign studies, the possibility (after completion of solidification of all foreseen INPP liquid radioactive waste or starting working in two shifts) of later utilization of the Cement Solidification Facility and the interim storage facility for the new NPP liquid radioactive waste solidification and storage also will be considered.

1.8.5 Electrical systems

The open power distribution system of the INPP will remain without changes during the decommissioning of the INPP and there will be no need to install a new electrical network. The condition of the existing power transmission lines depends on many factors and it should be checked before the start of the operation of the new NPP. Because of the importance of the transmission lines for the whole operation of the plant, it is economically viable to ensure the good condition of the transmission system and renew the parts of it that might be close to the end of their life span.

The 330/110 kV outdoor switchyard of the INPP has been in operation for nearly 25 years. By 2015 the major components will reach about 80 % of their expected life span. Due to the importance of the switchyard for the grid connection of the new NPP, it is suggested to replace the technology of the switchyard completely after the shutdown of the INPP. Following its rehabilitation, the switchyard may be reused. However, the location of it is relatively far from the site 1. In case site 1 is chosen for the implementation of the project, it should be studied, if it would be more convenient to build a completely new switchyard.

If the main transformers of the INPP should be reused, they would have to be relocated close to the turbine hall of the new NPP. The existing rail system of the INPP site area would make this operation manageable. However, the condition of the technology and its environmental feasibility should be studied more in detail before a decision on the reuse can be made.

1.8.6 Logistics

The main road connection from Visaginas to the INPP area can be used for the traffic also to the new NPP area. New access roads to the NNPP and to the relating facilities will have to be built when the site has been confirmed.

The site rail system of the INPP can be completely taken over and reused. Some smaller adaptations might be required.

1.8.7 Heat and steam sources

It is possible to use the existing heat only and steam only boilers of the INPP area for the purposes of the new NPP.

1.8.8 Monitoring systems

The existing monitoring systems and equipment will be used to the appropriate extent. However, they will be renewed according to the recent regulations and standards (see Chapter 9).

A seismic alarm and monitoring system of the INPP has been installed only recently. It comprises sensors located at distances of up to 30 km from the INPP which enables alerting prior to arrival of earthquake shock waves at the site. It identifies seismic events, does not interfere with other systems and its integration does not involve any risk for the NNPP supplier.

Some particular elements of the INPP off-site radiological monitoring system, e.g. the environmental monitoring laboratory with the meteorological observation station, could also be reused. However, the existing height of the meteorological measurement tower can be insufficient for the new NPP. Therefore during the designing of the new NPP the system assessment will be carried out and its renovation will be foreseen.

1.8.9 Other

The old construction storage and lay down area from the early site construction days equipped with rails connecting several storage halls and parts of the area is still suitable for use during the NNPP construction phase in case site 1 is chosen for the implementation of the project. The existing buildings of this area need to be renovated.

The pressurized air supply system of the INPP could technically be integrated into the new NPP. However, the simultaneous use of pressurized air for dismantling Units 1 and 2 of the INPP and for the operation of the new NPP would create a need for some changes in the system.

The N_2-supply system of the INPP has been used for heat removal of the RBMK graphite core. The system can be reused in case the new nuclear power plant is a BWR.

The hydrogen electrolysis plant of the INPP could be reused for the same purpose as now, i.e. cooling of the stator coils of the electric generator. Its capacity should be sufficient.

The fire fighting hydrant system is a part of a safety system and this is why reuse of the pumping station only should be considered. If the pumping station would need to be disassembled and reassembled, the reuse of it should not be considered.

The pipelines that have been used to supply hot water to the Visaginas district heating system have been renovated and may be used if the NNPP will be used to produce heat for the district heating.

The storage hall of INPP for new fuel is not suitable to be reused for the NNPP. Reasons for this are the hall’s location and building design, which might not comply with recent requirements.

New back-up diesel engines will be built for the NNPP.

The communication system of the INPP has been newly installed. However, it will most likely be outdated when the operation of the new plant starts and it might be economically more viable to build a totally new system than reuse the existing one. It is unlikely that the new administration of the modern power plant could settle in the INPP administration building of outdated structure; however, a possibility to use some of the INPP buildings, including the administrative building or the information centre (at least partially or temporarily) will be examined.

2 DESCRIPTION OF THE EIA PROCEDURE

2.1 GENERAL

Environmental Impact Assessment (EIA) is a process that predicts, examines and evaluates potential environmental impacts of a proposed economic activity and ensures that the decision makers know the public opinion before giving development consent and are provided with information about negative environmental effects, which might arise from development actions.

According to Lithuanian legislation, the EIA should be performed only for activities that have the potential for significantly affecting the environment due to the nature, size or proposed location of the activity. The activity of construction of nuclear power plants and other nuclear installations is included in the List of the Types of Proposed Economic Activities that shall be Subject to the Environmental Impact Assessment (*Annex 1 of the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity*, *State Journal*, *2005*, *No. 84-3105*). Therefore performance of EIA for this proposed economic activity is obligatory. The planned schedule of the EIA procedure for this proposed economic activity is presented in the following figure (Figure 2.1-1).

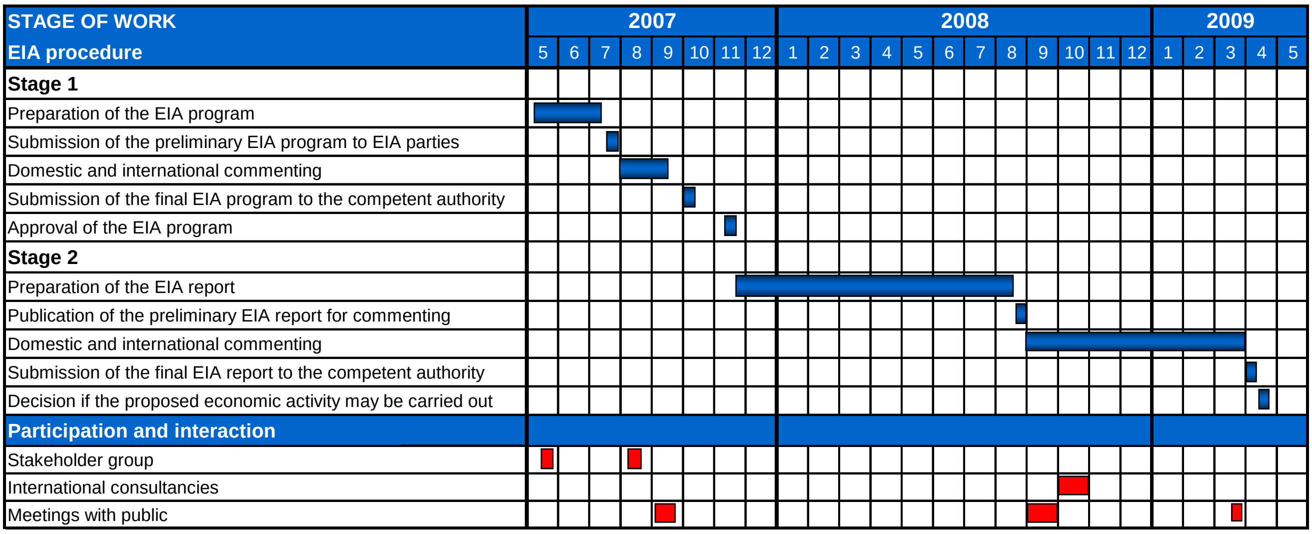

Figure 2.1-1. Schedule for the EIA procedure.

2.2 EIA PROCEDURE

The Law on Environmental Impact Assessment of Proposed Economic Activity of the Republic of Lithuania (*State Journal, 2005, No. 84-3105)* and regulations supporting the law define the legal requirements for the EIA procedure. This law implements the EU Directive 85/337/EEC (with amendments) on the assessment of the effects of certain public and private projects on the environment. The EIA is performed in two subsequent stages (Figure 2.2-1). In the first stage, the EIA program has been prepared and presented to the authorities and public for a review. The EIA program defines the scope and content of the EIA Report and has already been approved by the competent authority (Ministry of Environment of Lithuania). In the second stage, the EIA Report is prepared based on the approved EIA program and the opinions and statements. Before the competent authority decides if the proposed economic activity is permitted on the chosen site, the EIA Report is reviewed by the EIA Relevant Parties and public.

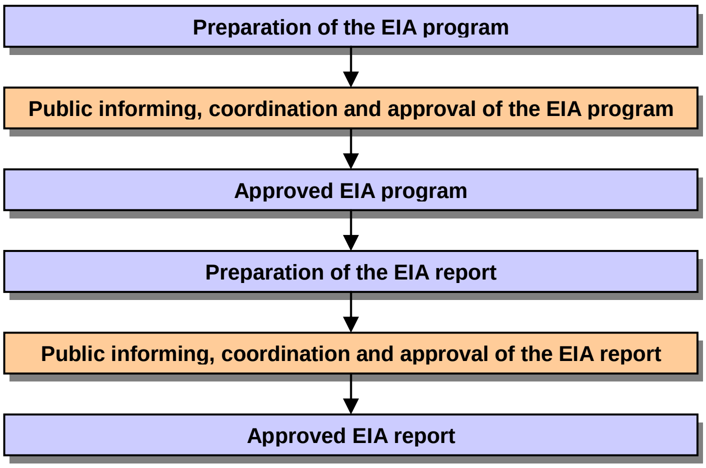

Figure 2.2-1. General overview of the EIA procedure.

2.3 PREPARATION OF THE EIA REPORT

The Environmental Impact Assessment Report is prepared by the Developer of the Environmental Impact Assessment documents according to the program, approved by the Competent Authority. All the issues, foreseen in the program, are thoroughly analyzed in this Report. Implementation of procedures for the EIA Report is presented in Figure 2.3-1.

The Organizer of the Proposed Economic Activity according to the order, established by the Ministry of Environment, organizes the presentation of the Report to the public. The Developer of the Environmental Impact Assessment documents, according to the motivated suggestions made by the interested public, presents the updated Report to the Relevant Parties. The Relevant Parties check whether the Report thoroughly analyzes issues in their competence, foreseen in the program.

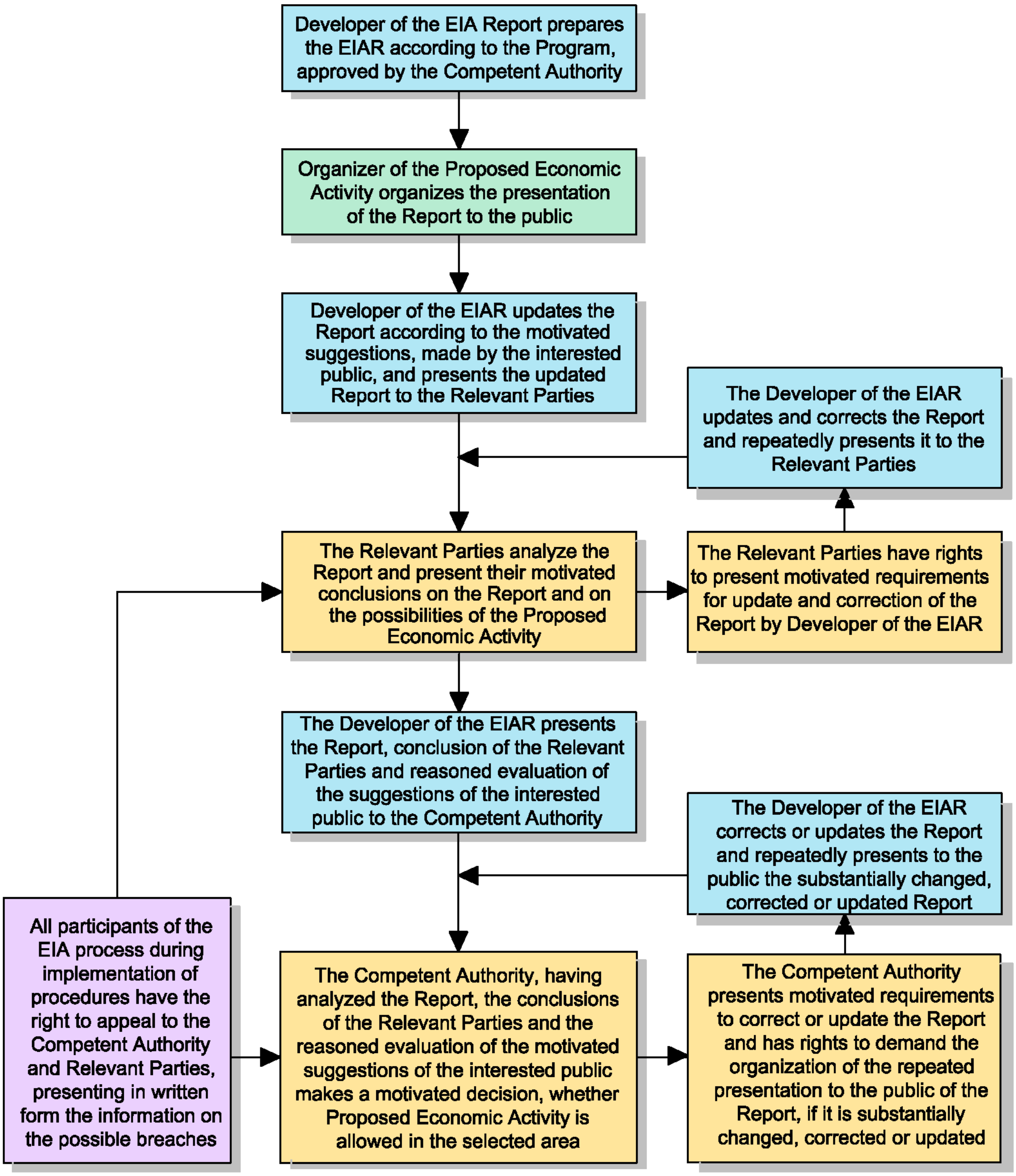

Figure 2.3-1. Implementation of procedures for EIA Report.

The Relevant Parties analyze the Report, and within 20 working days from its reception present their motivated conclusions on the Report and on the possibilities of the Proposed Economic Activity to the Developer of the Environmental Impact Assessment documents. The Relevant Parties have the right to present motivated requirements for update and correction of the Report by the Developer of the Environmental Impact Assessment documents. The Developer of the Environmental Impact Assessment documents has to update and correct the Report and present it again to the Relevant Parties. The Parties analyze the Report and within ten working days from its reception present motivated conclusions on the Report and on the possibilities of the Proposed Economic Activity to the Developer of the Environmental Impact Assessment documents.

The Developer of the Environmental Impact Assessment documents presents the Report, conclusion of the Relevant Parties on the Report and the possibilities of the Proposed Economic Activity, and reasoned evaluation of the suggestions of the interested public to the Competent Authority. The Competent Authority has the right to demand the organization for a repeated public introduction of the Report, if, after the public introduction of the Report, it has been substantially changed, corrected or updated (for instance, new locations, technological alternatives, impact mitigating measures, etc. are suggested) due to motivated conclusions, received from Relevant Parties and motivated requirements by the Competent Authority to correct or update the Report.

All the participants of the EIA process during the implementation of procedures on the Environmental Impact Assessment of the Proposed Economic Activity have the right to appeal to the Competent Authority and Relevant Parties on the issues of their competence, until the Competent Authority makes a decision. In their appeal the participants need to present in written form the information on the possible breaches establishing, characterizing and assessing the possible environmental impact due to Proposed Economic Activity or when implementing Environmental Impact Assessment procedures.

2.4 INFORMING THE PUBLIC

An EIA process ensures effective and well-timed public participation and consultation. All interested citizens and interest groups have the right to express their opinions at virtually every stage of the EIA process. The reasons why the public must be involved in the EIA process include:

- local inhabitants may provide local expertise and knowledge;
- public participation may help to identify the important issues or concerns determining the scope of the EIA;
- local inhabitants may propose additional project alternatives;
- public participation ensures that possible later conflicts will be avoided;
- positive public opinion might serve as a useful additional argument when requesting development consent;
- public participation ensures the openness of the EIA and the acceptability and credibility of EIA decision-making.

Non-governmental organizations (NGOs) and community groups might significantly contribute at the practical and policy levels of EIA process. They can provide a point of contact and organize public and informal meetings. In addition, NGOs can often provide considerable expertise and experience which is unavailable to consultants, developers or public authorities. They usually have links with other NGOs, international specialists and advisers as well as a network of volunteers and staff with direct and often extensive EIA experience in dealing with policy and decision makers.

The Law on Environmental Impact Assessment of Proposed Economic Activity of the Republic of Lithuania (*State Journal, 2005, No. 84-3105)* defines the rights and functions of the public, ensuring public participation throughout the whole process of Environmental Impact Assessment. Procedural details of public participation are provided in the Order of Informing the Public and Public Participation in the Process of Environmental Impact Assessment, approved by the Ministry of Environment (*State Journal, 2005, No. 93-3472).*

2.5 ENVIRONMENTAL IMPACT ASSESSMENT IN A TRANSBOUNDARY CONTEXT

In cases when an economic activity that is proposed to be carried out in the territory of the Republic of Lithuania may cause a significant negative impact on the environment of any other State that has signed the United Nations Convention on Environmental Impact Assessment in a Transboundary Context (*Espoo Convention, 1991. State Journal, 1999, No. 92-2688*), or upon request of such a State, the public is participating in the process of environmental impact assessment in accordance with the requirements of the above mentioned Convention, international agreements between relevant States and the Republic of Lithuania, the Law on Environmental Impact Assessment of Proposed Economic Activity of the Republic of Lithuania (*State Journal, 2005, No. 84-3105)*, and other relevant legal acts.

The EIA process is performed in compliance with the Espoo Convention. The Competent Authority has to inform the countries which might suffer the detrimental environmental impacts of the proposed economic activity. After the Competent Authority gets the responses from the countries concerned and their comments on the EIA Report, it delivers them to the organizer of the proposed economic activity.

2.6 DECISION ON THE POSSIBILITIES OF THE PROPOSED ECONOMIC ACTIVITY

After analyzing the Report, the conclusions of the Relevant Parties on the possibilities for the Proposed Economic Activity, the reasoned evaluation of the motivated suggestions of the interested public and motivated suggestions, presented in a written form by the interested public, within 25 working days from the reception of the Report the Competent Authority

1) presents motivated requirements to correct or update the Report;
2) makes a motivated decision, whether the Proposed Economic Activity, with the respect to requirements of relevant laws and regulations, the character of activity and (or) environmental impact, is allowed in the selected area.

The Competent Authority presents a motivated decision in a written form to the Relevant Parties and to the Organizer of the Proposed Economic Activity or to the Developer of the Environmental Impact Assessment documents.

When the conclusions of the Relevant Parties on the possibilities of the Proposed Economic Activity contradict one another, the Competent Authority, before making a decision, invites the Relevant Parties to participate in the process of discussion of their conclusions. It also invites the representatives from public, who had presented motivated suggestions.

If it is determined that the implementation of the Proposed Economic Activity causes significant negative effects to the areas of the European Ecological Network “Natura 2000” and there are no alternative ways of decision for activities, the Proposed Economic Activity may be allowed only in those cases, when its decisions are related to public health, preservation of certain environmental components or taking into consideration the opinion of the European Commission, and for other significant reasons. In such cases, all possible compensating measures, necessary for preservation of integrity of the areas of the European Ecological Network “Natura 2000” have to be foreseen and implemented. The authority in charge of the organisation of the security and management of protected areas (the State Service for Protected Areas) informs the European Commission about these compensation measures, following the Order on Strategic Evaluation of Environmental Results of Plans and Programs, approved by the Ministry of Environment (*State Journal, 2004, No. 130-4650)*.

If the Competent Authority makes a decision that the Proposed Economic Activity due to breaking of requirements of relevant laws and regulations and (or) possible negative impact to the environment is not allowed in the selected area, the Proposed Economic Activity may not be implemented.

The Competent Authority and the Organizer of the Proposed Economic Activity, according to the requirements of the Order of Informing the Public and Public Participation in the Process of Environmental Impact Assessment (*State Journal, 2005, No. 93-3472),* present the motivated decision to the public on whether Proposed Economic Activity, taking into consideration requirements of the relevant laws and regulations, the nature of activity and impact to the environment, is allowed in a selected area, and give the opportunity to get acquainted with it.

The positive decision made by the Competent Authority on the opportunities of the Proposed Economic Activity is valid for five years from the public notification day.

3 COMMUNICATION AND PARTICIPATION

3.1 GENERAL

One of the objectives of the EIA procedure is to increase availability of information of the proposed economic activity and improve the opportunities for citizens' participation. In the following the means of communication and interaction in the EIA procedure of the new nuclear power plant are described. Parties involved in the EIA procedure are presented in the following figure (Figure 3-1).

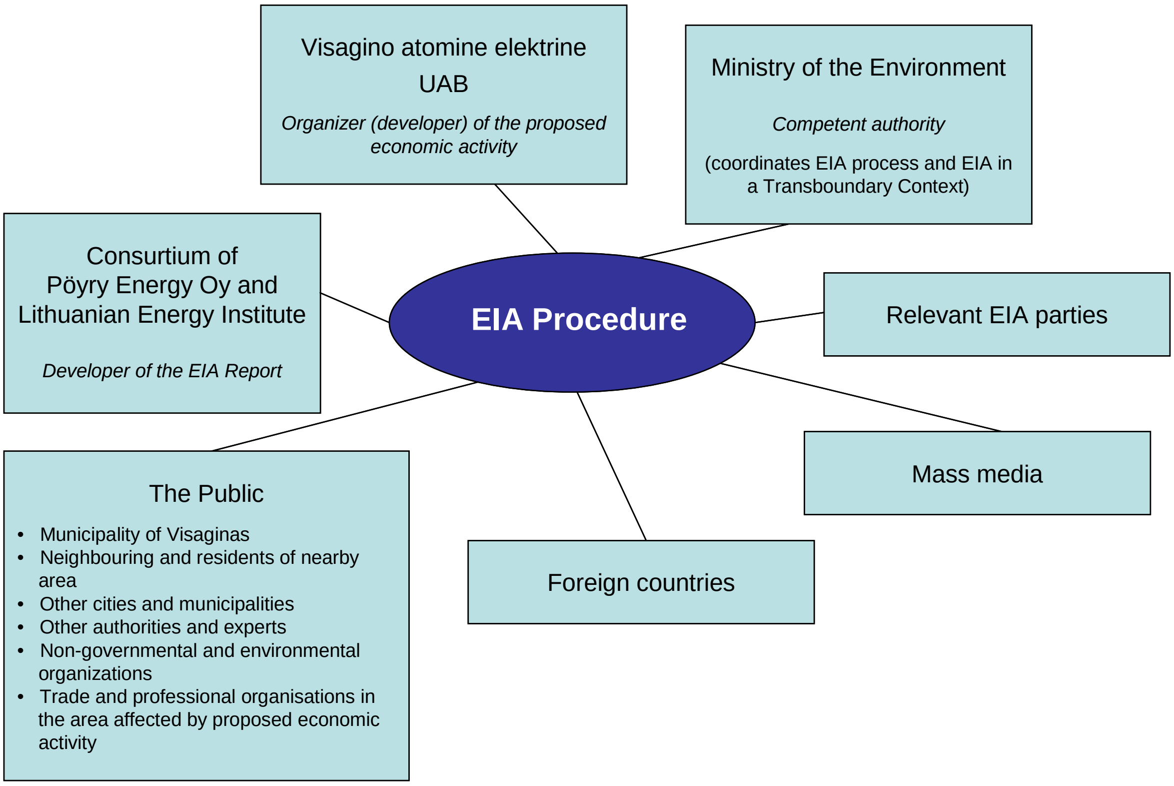

Figure 3.1-1. Parties involved in the EIA procedure.

3.2 CONSULTATIONS WITH COMPETENT AUTHORITY AND RELEVANT EIA PARTIES

Competent authority of this proposed economic activity is the Ministry of Environment. The competent authority coordinates all EIA process and transboundary environmental impact assessment. Based on the letter of the Ministry of Environment, the relevant EIA parties are:

- State Nuclear Power Safety Inspectorate (VATESI),
- Radiation Protection Centre,
- Fire Protection and Rescue Department,
- Utena Public Health Service,
- Utena Region Environmental Protection Department,
- State Service for Protected Areas;
- Cultural Heritage Protection Department,
- Utena County Governor's administration,
- Administration of Visaginas Municipality,
- Administration of Ignalina district Municipality,

- Administration of Zarasai district Municipality.

Consultations have been carried out with the competent authority and relevant EIA parties, but the opinions expressed do not oblige the parties giving the official statements.

In the first consultation meeting in May 24, 2007 the project, the EIA procedure, interaction and the planned main content of the EIA Program were presented and discussed.

Comments and clarifications received during and after the meeting were taken into account in the preparation of the EIA Program to the widest possible extent as far as they concerned the EIA Program. The second consultation meeting has been carried out in August 14, 2007 after the EIA Program had been submitted for relevant EIA parties and public review. In the meeting the contents of the EIA Program and the impacts to be assessed in the process were presented and discussed.

During the EIA Report stage consultations with the competent authority and relevant EIA parties have been organized to discuss the assessment of the possible impact on Lake Druksiai, the possible radiological impact and the risk analysis.

3.3 INFORMATION AND DISCUSSION EVENTS

Information and discussion events open to the public are arranged during the preparation of the Environmental Impact Assessment Program and Report. At the events the general public has the opportunity to discuss and express their opinions on the EIA work and its sufficiency and to receive information about the new nuclear power plant project and the EIA procedure from the project organisation and the developers of the EIA Program and the EIA Report.

The EIA Program for the new NPP was presented to the public of Lithuania and the neighbouring countries in three public meetings during the autumn of 2007.

On September 3rd, 2007 a public discussion event was organized on the EIA Program in Daugavpils, Latvia. The discussion was attended by Lietuvos Energija AB, the developers of the EIA Program, the representatives from the Ministry of Environment of Lithuania, representative from the Ministry of Environment of Latvia and representatives from the Latvian Radiation Security Centre and the Latvian Hazardous Waste Management Agency in addition to the Latvian residents of the region.

On September 14th, 2007 a presentation of the EIA Program and a discussion with the members of the municipal communities of Visaginas, Ignalina and Zarasai regions took place in Visaginas.

On September 26th, 2007 a meeting with representatives of various scientific organizations was organized in Vilnius.

On September 27th, 2007 a public discussion between the organizers of the EIA and the Estonian public was also organized in Tallinn, Estonia. The event was attended by Lietuvos Energija AB, the developers of the EIA Program, representatives from the Ministry of Environment of Estonia, members of the Estonian Parliament as well as public organizations and communities.

On August 27, 2008, the EIA Report was published and according to the procedure, set out by the Ministry of Environment, the organiser of the proposed economic activity arranged a presentation of this report to the public. The public of Lithuania and the neighbouring countries was acquainted with the EIA report of the new NPP at six public meetings during the autumn of 2008.

On September 23rd, 2008 the EIA report was presented to the general public during a meeting at the municipality of Visaginas. The developers of the EIA report presented the report to the people of Visaginas, Zarasai and Ignalina. Also on September 24th a public meeting was organized in Vilnius in the conference hall of Lietuvos Energija AB.

On October 1st, 2008 the EIA Report was presented to the Estonian public in Tallinn. The meeting was attended by the developers of the economic activity, the developers of the EIA Report, representatives of Estonian ministries as well as public organizations and communities. The public asked questions for example about the schedule of the activity, the risk analysis and the decommissioning of the NNPP.

On October 8th, 2008 a public discussion on the EIA Report was held in Daugavpils, Latvia, in the Municipal Conference Hall. During the discussion, the Latvian public was mainly interested in the potentially positive impacts on the socio-economic environment mentioned in the EIA Report, the impact on public health, the proposed technological changes (including details of the future reactor’s design), and the disposal of radioactive waste.

On October 9th in Riga Latvia a public hearing was organized in the conference hall of the Latvian Ministry of Environment. During the discussion the Latvian public was mostly interested in the positive impacts on the socio-economic environment in Latvia, course of the Project, alternative technologies discussed in the Report, particulars of various technologies and impact of radiation on public health, and asked questions about the disposal of radioactive waste.

On October 14th a public hearing was organized in Breslaw in Belarus. Representatives from various science, medicine, municipal and public agencies as well as people living in the vicinity of the Lithuanian border with Belarus wanted to know about the impacts that the NNPP in Lithuania will have on the general population and natural environment, the differences between the two alternative site locations, how the developers intended to inform the public, systems of monitoring and policies of the disposal of accumulated radioactive waste. During the discussion, people made a number of proposals concerning provision of information to public on the course of construction of the NNPP and a set up of an information centre.

3.4 PUBLIC DISPLAY OF THE EIA PROGRAM AND EIA REPORT

In both the EIA Program and the EIA Report stage the organiser (or developer of EIA documents) of the proposed economic activity informs the public about the EIA Program and the EIA Report in accordance with requirements of the Order of Informing the Public and the Public Participation in the Process of Environment Impact Assessment (*State Journal, 2005, No. 93-3472*). The public has the right to examine the EIA Program and the EIA Report and express their opinions about them. The developer of EIA must perform the registration of received motivated (justified) proposals, reasonably evaluate them and attach them as appendixes to the approved EIA Program or the approved EIA Report.

The residents of the nearby area were able to get acquainted with the EIA Program from July 30th to August 20th, 2007 in Lithuanian Energy Museum, in the administration of the municipalities of Visaginas town, Ignalina and Zarasai regions, and in the lobby of Lietuvos Energija AB. The presentation took place for 15 working days. The advertisement for the presentation of the EIA Program to the public was published in all the republican daily newspapers: the Lietuvos Rytas, the Respublika (in the Lithuanian and Russian languages), the Lietuvos Zinios, the Kauno Zinios, the Versio Zinios, the Valstieciu Laikrastis and the regional newspapers of Visaginas, Ignalina and Zarasai.

The proposals by the public concerned for example the usability of the existing infrastructure of the INPP, the impacts of the project on Lake Druksiai and the possibilities to use indirect cooling. Some proposals concerned issues that are not in the scope of the EIA process, like technical and economical aspects that are evaluated in separate feasibility studies. The proposals and responses have been attached as appendix to the approved EIA Program (in the original Program in Lithuanian language).

The EIA Report was made available for public display on 27 August 2008. The general public could get acquainted with the NNPP EIA Report in Ignalina, Zarasai and Visaginas municipalities, or in the ground floor lobby of Lietuvos Energija headquarters in Vilnius. The motivated (justified) proposals, that have been received, are registered, evaluated and attached as appendixes to the approved EIA Report.

3.5 REVIEW OF EIA PROGRAM AND EIA REPORT BY RELEVANT PARTIES

Relevant parties of the environmental impact assessment assess the EIA Program and Report and have a right to give their conclusions to the organiser (developer), who has to take them into account. The relevant parties include the State Nuclear Power Safety Inspectorate, the Radiation Protection Centre, the Fire Protection and Rescue Department, Utena Public Health Service, Utena Region Environmental Protection Department, the Cultural Heritage Protection Department, Utena County Governor's administration, Administration of Visaginas Municipality, Administrations of Ignalina and Zarasai District Municipalities and the State Service for Protected Areas. Their review has an important role in ensuring the quality of the EIA process.

The procedure of the review by the relevant parties is described more in detail in Section 2.3.

3.6 COORDINATION OF EIA PROCESS BY COMPETENT AUTHORITY

The competent authority, the Lithuanian Ministry of Environment, is responsible for the coordination of the EIA process and fulfils its functions set out in the Law on the Assessment of the Impact on the Environment of the Planned Economic Activity (*State Journal 2005 No. 84-3105*).

The EIA Program was first submitted to the Ministry of Environment for comments and approval on October 4, 2007. Lietuvos Energija AB received comments and proposals (47 comments) for the EIA Program from the Ministry of Environment on October 19, 2007. The EIA Program was revised and supplemented accordingly and submitted for approval on October 29, 2007. The EIA Program was approved by the Ministry of Environment on November 15, 2007.

Within 25 working days since the EIA Report is presented, the competent authority can give justified request to revise and/or amend the Report or make a justified decision that this activity, taking into account the requirements of the relevant legislation and regulations, by virtue of its nature and environmental impacts can be carried out in the chosen site. More detailed information is presented in Section 2.6.

3.7 OTHER COMMUNICATION

The project organization provides information on the project through press releases or press briefings. Also summary brochures have and will be prepared for communication. The first brochure was prepared in early 2008 once the EIA Program was completed. It describes the project, the EIA procedure and summarizes the contents of the EIA Program. The second summary will be prepared once the EIA Report is completed. It will describe the project and the most important results of the environmental impact assessment.

Information about the EIA procedure is also provided at the new NPP project website http://www.vae.lt. The website provides up-to-date information on the progress of the EIA procedure. The EIA Program and EIA Report are available in the Lithuanian, English and Russian languages, and the Summary of the EIA Report is available in German, Estonian, English, Finnish, Latvian, Polish, Russian and Swedish languages on the website. The project website has been actively visited by both Lithuanian and foreign public. During the period 1.8.2008-1.1.2009 there were 24 000 unique visits to the website. In total the number of visits was 40 000 of which 11 000 were from Lithuania. During January 2009 the total number of visits was 4 800.

3.8 ENVIRONMENTAL IMPACT ASSESSMENT IN A TRANSBOUNDARY CONTEXT AND THE IAEA MISSION

Environmental impact assessment in a transboundary context is regulated by the Law on the Assessment of the Impact on the Environment of the Planned Economic Activity (*State Journal 2005 No. 84-3105*) and by the United Nations Convention on Environmental Impact Assessment in a Transboundary Context (*Espoo Convention*).

The parties to the Convention are entitled to participate in an environmental impact assessment procedure carried out in Lithuania if the detrimental environmental impacts of the project could potentially affect the country in question. Correspondingly, Lithuania is entitled to participate in an environmental impact assessment procedure concerning a project located in the area of another country if the impacts of the project could potentially affect Lithuania.

The Ministry of Environment is responsible for the practical organization of the environmental assessment procedures in a transboundary context. The Ministry of Environment has informed the respective authorities of Latvia, Estonia, Poland, Belarus, Finland, Sweden and Russia about the commenced environmental assessment process of the new nuclear power plant in Lithuania and inquired about their intent to take part in the environmental assessment procedure. Russia did not express an intent to take part in EIA process, and Austria on its own initiative wished to be included into the environmental assessment procedure. The information letter was supplemented with the EIA Program in English or Russian and a comprehensive summary in each country's official language was attached. The above mentioned countries had an opportunity to present their suggestions and comments on the EIA Program, which were taken into account by the developer of the EIA documents.

Austria, Belarus, Estonia, Finland, Latvia and Sweden presented their remarks on the EIA program of the new NPP. These comments were taken into account when preparing the EIA report. The summarized responses to the foreign countries‘ remarks about the EIA program are presented in the appendices of the EIA report. Subsequently, the countries, participating in the EIA process of the new NPP, were provided with the EIA report (the issue date of the report - 27 August, 2008). Austria, Belarus, Estonia, Finland, Latvia, Poland and Sweden submitted their remarks and recommendations to the EIA report. It should be noted that from the foreign countries participating in the EIA process only Belarus, Latvia, Poland and Austria expressed the wish to hold further consultation meetings on the issues of the largest concern for them. Authorities of Belarus, Latvia, Poland and Austria responsible for the EIA process submitted comments and conclusions of their experts to the Ministry of Environment. Later on the aforementioned comments and conclusions, in the presence of foreign experts, professionals of the Ministry of Environment, the EIA relevant parties, the organizer of the planned economic activity, as well as the developer of the EIA report, were discussed during interstate consultations, held in Vilnius:

- On 19 November, 2008 – with the Austrian experts;
- On 18 December, 2008 – with the Polish experts;
- On 22 December, 2008 – with the Belarusian experts;
- On 9 February, 2009 – with the Latvian experts.

The questions and answers that were discussed during the interstate consultations with Austrian, Polish, Belarusian and Latvian experts are summarized in Table 3.8–1, Table 3.8–2, Table 3.8–3 and Table 3.8–4.

Remarks on the EIA report of Estonia, Finland and Sweden, as well as comments of foreign non-governmental organizations and answers to them are submitted in the appendices of the EIA report.

On 26–30 January, 2009, in Lithuania a special mission of International Atomic Energy Agency (IAEA) experts from Argentina, Austria, France and Great Britain was organized by the Ministry of Environment and VATESI. The purpose of the mission was to review the procedures of execution of environmental impact assessment in Lithuania and the EIA report itself, as well as to assess its compliance with the best international practices and procedures from radiation protection and environmental point of view. In accordance with their field of activity the experts of the IAEA mission analysed in detail the information, presented in the EIA report, and expressed the opinion that the EIA report included sufficient information and data to allow for a decision on the admissibility of the activity from environmental impact point of view. Moreover, the IAEA experts made many useful comments and observations on how to improve the quality of the EIA report, which were taken into account in the latest version of the EIA report.

Table 3.8–1. Questions and responses discussed during the consultations with Austrian experts.

No.	Question	Response
	Management of nuclear waste	
1.	Management of spent fuel and HLW is not described adequately in the EIA report. Options for interim storage of spent fuel and for long-term storage are only discussed in general, but there is no management concept presented.	During the operation of NNPP the SNF and radioactive waste will be stored in appropriate storage facilities which are a part of NPP. Environmental impacts from these facilities in terms of total radioactive releases from NPP are estimated in this EIA Report. Different SNF further management and disposal options (pool type and dry storage facilities away from the reactor, reprocessing; national/regional deep geological repository, etc) are listed in EIA Report. However, these activities will the separate projects and their own EIA procedures will be implemented in due time. Also it should be noted, that existing worldwide experience as well as experience of Ignalina NPP, shows that SNF and radioactive waste for a long time can be stored in appropriate facilities safely and without significant impacts to environment.
2.	Is it possible to provide a short overview	An updated Radioactive Waste Management

No.	Question	Response
	of the nuclear waste management concept with the focus on HLW and spent fuel, because the National Strategy on Radioactive Waste Management from 2002 was not available in English from the homepage of RATA?	Strategy was approved at September 2008. Presently the strategy is available only in Lithuanian language. Short overview will be provided during the meeting on 19 November 2008.
	Reactor types and safety standards	
3.	Is it correct that only four Western reactor vendors are under consideration to supply the new NPP in Lithuania and what is the reasoning behind this decision?	In the EIA Report reactor types are taken into account from the following vendors: - Areva NP - Atomic Energy of Canada Limited - Atomstroyexport - GE-Hitachi - Mitsubishi Heavy Industries - Westinghouse-Toshiba Final decision on which vendor will supply the reactor for NNPP will be made after the tendering process, which is a further step after EIA.
4.	What are the further steps in the selection of the reactor type and the development of the plant?	If Competent authority based on EIA Report makes the decision that the economic activity, by virtue of its nature and environmental impacts, may be allowed to be carried out in the chosen site, the further main project steps are as follows: - Preparation of Technical specification for NNPP; - Tendering process; - Preparation of technical design documentation (TDD) for selected reactor type; - Preparation of safety justification documents (safety analysis report; PSA ; etc.) for selected reactor type; - Licence for construction; - Licence for operation.
5.	Which documents will be available for foreign states participating in the cross border EIA during the selection procedure of the reactor type and how will they be informed about decisions?	According to Lithuanian legislation there are no requirements to submit TDD or safety justification documentation for foreign states. The Ministry of Environment of the Republic of Lithuania will provide to the potentially affected states the decision regarding the feasibility of the proposed economic activity considering its environmental impacts.
6.	Which requirements are of priority for the selection of the reactor type?	The reactor type to be chosen for the NNPP in Lithuania shall be safe, employ proven technology and be in line with the most recent developments in nuclear technology. All 11 reactor designs, assessed in the EIA, are generation III or III+ reactors.
7.	Which safety features and safety criteria will be of relevance for the selection of the reactor type? In particular the following issues should be clarified:	See response to Question 4 above which describes subsequent steps in the specification, selection and licensing of the new NPP. Lithuanian regulations for issue of a licence to

No.	Question	Response
	- the relevance of PSA results compared to deterministic safety assessment - CDF / LRF relation - the relevance of mostly active to mostly passive safety systems - the assessment of in-vessel vs. ex-vessel cooling as severe accident management measure - a more detailed description of the requirements concerning the vulnerability of the plant to external hazards	construct and operate a Nuclear Facility (including NPP) are in place and in line, as a minimum, with current IAEA guidance. The EIA indicates that the project will take cognisance of the European Utilities Requirements Document (EURD), which contains both deterministic and probabilistic criteria. The EIA severe accident scenario is selected to be independent of the technology, to illustrate the consequences should such an unlikely event occur. As such, all candidate designs would be expected to satisfy the severe accident case presented. The definitive accident consequences will be provided to the relevant authorities as part of the Final Safety Analysis Report.
8.	Because details of safety standards for new NPPs are not mentioned in the EIA Report, and there is no reference to documents containing further information concerning standards for new plants, it appears that their development is in a very early stage. Therefore, we request a more detailed description of the procedure to develop those standards, including an explanation of how this procedure will be timed in relation to the new NPP project, and how it will interact with the development of the project.	Development of safety standards, licensing issues, review and approval of safety analysis reports and other issues related to safe operation of a nuclear facility are in competence of State Nuclear Power Safety Inspectorate. However, these questions are not within the scope of EIA.
	Accident Analysis	
	Long range consequences:	
9.	The 98th percentile does not indicate the worst case. As shown in the statement, there are (summing night time and daytime releases) 1460 cases. Even if these cases are too episodic to assign them a reliable statistical probability, the calculations still show that they would be possible, and it would be relevant to Austria and its inhabitants to know these cases, or at least the worst ones that were found with respect to the conditions in Austria. In order to enable such inferences, we request more information on these upper 2% of the cases. This could be accomplished by giving us either - maps, or - gridded values of the deposition and the total committed external doses, for either all the 1460 cases or - for the upper 2% of the data	Information requested is not available since the analysis has not been performed as straight-forward cases from release to dose. The analysis consisted of three steps: - Computation of a large number of individual cases of dispersion (for LOCA, SA and constant source) and compiling the dispersion data archive. Obtained results were maps of concentrations and depositions resulting from dispersion for many individual cases. - Statistical analysis of the obtained dispersion results, computation of probability distribution functions and corresponding percentiles for dispersion pattern. This provided a statistical description of the dispersion pattern: maps of concentrations and geographical distribution of probabilities of specific levels to be reached or exceeded during accidents. - Computations of the upper percentiles of doses using the upper percentiles of concentrations and depositions as an input.

No.	Question	Response
		The 98% of concentration and depositions were taken as the main characteristics of the analysis to obtain reliable answers and to keep the amount of computations under control. The information is place-specific, i.e. the assessment results in maps of the percentiles. As stated in the EIAR, a value of 98% means that in 2% of cases will the estimated impact be exceeded. Given the frequency of the Limiting Design Basis Accident is <1E-05/ year, and the assessed severe accident is <5 E-7 per year, the boundary of the consequences identified in the EIAR is ~1E-07/ y and 1E-09/y respectively, i.e. extremely low likelihood.
	Severe accident source term	
10.	Is it possible to present more information from PSAs which give an adequate illustration of the radiation hazard in case of severe accidents instead of an arbitrary chosen source term (including the contributions of different initiating events and plant states, as well as a discussion of limitations and uncertainties)?	The further steps of the project are listed in the response to comment No. 4. PSA and safety analysis will be developed after the EIA process is finished, therefore it is not possible to provide detailed information in the EIA Report.
11.	Independent of the probability of occurrence it would be important to discuss early and large releases due to severe accidents in order to find out the relevant emissions for transboundary impact assessment. In published design control documents some data on release rates of BDBA in generation III reactors can be found, can you provide such information for the candidate reactors?	Releases in case of Severe accident are estimated according to Finnish experience and regulations for severe accident releases. Data on release from design control documents can be extracted. However, this data is not available for all type of reactors and is more relevant for PSA than EIA Report.
	Need for new electricity capacities and cost effectiveness of the NPP project	
12.	How will structural changes, energy efficiency policy and economic development impact the development of the yearly electricity consumption in the different demand sectors and sub-segments by 2025? Which comprehensive demand forecast model (and the respective parameters) was used to simulate these effects?	The objectives of the EIA are defined in Article 4 of the Republic of Lithuania Law on Environmental Impact Assessment of the Proposed Economic Activity (State Journal, 2005, No. 84-3105). This Law on EIA is also harmonized with Council Directive 85/337/EEC and Espoo Convention. The objectives of the EIA are as follows: - to identify, characterize and assess potential direct and indirect impacts of the proposed economic activity on human beings, fauna and flora; soil, surface and entrails of the earth; air, water, climate, landscape and biodiversity; material assets and the immovable cultural heritage, and interaction among these factors; - to reduce or avoid negative impacts of the to reduce or avoid negative impacts of the proposed economic activity on human beings
13.	What are the main influence factors on base load demand and how are they assumed to develop by 2025? Are historic data available on the development of the base load demand during the last five years?	
14.	What have been the input parameters for NPP cost, mainly related to: over-night construction cost, construction time,	

No.	Question	Response
	reliability of operation, O&M costs, back fitting costs, back-end costs (decommissioning and nuclear waste management) and the respective interest rates, period of assessment?	and other components of the environment, referred to in paragraph above; and - to determine, if the proposed economic activity, by virtue of its nature and environmental impacts, may be allowed to be carried out in the chosen site. According to legislation cost estimation, energy efficiency policy, project validity and other economical/financial issues are outside the scope of EIA. These issues are considered in National Energy Strategy and other relevant documents (i.e. IAEA-TECDOC-1408 “Energy Supply Options for Lithuania”; IAEA-TECDOC-1541 “Analyses of energy supply options and security of energy supply in the Baltic States”).
15.	In which way has the considerable potential of CHP in the district heating sector resp. in the industrial sector been taken into consideration?	
16.	In which way has RES electricity production, which is assumed to increase steadily due to the EU policy framework, been taken into account?	
17.	In which way has the increasing integration of the Baltic electricity system to the Nordic and the UCTE systems been taken into account (relevant for an analysis on the system level)?	

Table 3.8–2. Questions and responses discussed during the consultations with Polish experts.

No.	Question	Response
1.	When considering environmental impact assessment of a nuclear power plant in a transboundary context, a threat of a potential serious accident and related radiological contamination cannot be excluded. Basing on the directions of air mass movements it can be stated that the North-eastern part of Poland or Warmian–Masurian province can be contaminated first of all. In order to guarantee the nuclear safety the construction of the power plant should be performed after the highest standards of designing, construction and operation of nuclear facilities have been assured.	The estimation of spreading of radionuclides released into the environment during a severe accident is presented in Subsection 10.3.2 of the EIA report. The distance of the estimation of radionuclide spreading, radioactive contamination and doses caused by a severe accident reaches up to 1200 km and includes many European countries, including Poland. The results shown in the maps of the modelling results correspond to 98% probability that in case of an accident there will be such situation. No doubt, the power plant design, construction and operation will be carried out in accordance with the requirements of radiation and nuclear safety, as well as with other standards relevant for construction and operation of such facility. All of these steps are supervised and controlled by the authorities responsible for nuclear and radiation safety, as well as for civil defence, etc. Besides, the additional expertises are conducted by foreign experts.
2.	The analysis of the submitted report on the impact of construction and operation of the aforementioned facility shows that after replacement of the existing nuclear units by up-to date ones, with total power not exceeding 3400 MW, this investment will significantly reduce the threat of potential	The RBMK-1500 reactors, currently operated by Ignalina NPP, are reactors of Generation II. After the accident at Chernobyl NPP, with the assistance of international organizations, additional safety measures were installed at Ignalina NPP in order to assure that an accident of the Chernobyl NPP type and scale

No.	Question	Response
	consequences of accidents in this power plant for the territory of the Republic of Poland.	would not occur. However, during the meeting of the finance ministers of the world's seven industrialized countries group in Munich in 1992 a political decision was made that the RBMK reactors are in principle insecure. The new NPP is planned to be provided with reactors of Generation III/III+, which are more advanced and safer than the reactors of Generation II. In addition, they will have containments, which the RBMK reactors do not have. Thus, in general the risk of accidents and the scale of the consequences of accidents will decrease.
3.	Nevertheless, the Polish party supposes that the submitted documentation contains some inaccuracies and mistakes in several points that should be corrected. Particularly the conclusions on the limits of severe accident impact and emergency response arrangements, including iodine prophylaxis in Table 10.4-3 on page 511 of the report, and the summary in Polish in Section 10.2, page 21 (24), require explanation, since it contradicts the results of calculations, given in the diagrams of the report (p. 501-505), as well as verification calculations of these results, carried out at the Emergency Centre CEZAR of State Atomic Energy Safety Inspectorate, validating the results presented in the diagrams.	The EIA developers had no possibilities to get familiarized with the verification calculations carried out by the CEZAR and the results obtained, therefore it is quite difficult to explain the differences between the calculations of CEZAR and FMI. We agree that the EIA report could contain some inaccuracies that are corrected when detected. According to Article 19 of Lithuanian hygiene standard HN 99:2000 "Protective Actions of Public in Case of Radiological or Nuclear Accident", the intervention level of iodine prophylaxis the avertable dose to the thyroid gland of ≥ 100 mGy (to newborns, infants, children, adolescents, pregnant and nursing women ≥ 10 mGy). These levels meet the levels applied in the foreign standards as well. However, Article 20 of HN 99:2000 20 also states operational intervention levels at which iodine prophylaxis is recommended. These levels were taken into account in the EIA report, thus there was obtained relatively large area, where iodine prophylaxis is recommended. If only the criterion of the avertable dose to the thyroid gland was applied, the area of iodine prophylaxis would be significantly smaller.
4.	Moreover, the report does not contain an explanation about radioactive waste and spent nuclear fuel (however, the document indicates that this topic will undergo a separate consideration), as well as about electrical power transmission and impact due to construction of electrical transmission lines.	The different radwaste and SNF management and disposal options are described in Chapter 6 according to Lithuanian National Strategy on Radioactive Waste Management. During operation of the NNPP SNF is stored in storage pools adjacent to the reactor. The impact of this intermediate storage of NSF has been assessed in the EIA report. Long term SNF storage, as well as SNF and radwaste disposal depends on the technologies and methods that will be employed in future; therefore their impacts cannot be estimated at present. The EIA of

No.	Question	Response
		the NNPP mentions that this will be addressed in separate EIA reports. When constructing Ignalina NPP it was planned that it would consist of four units with total electrical capacity of 6000 MW. The existing infrastructure of transmission of electrical energy was envisaged for the transmission of such capacity; therefore new transmission lines for transmission of electrical energy, produced by the new NPP will not be needed.
5.	When talking about Natura 2000 territories, documentation of assessment of impact on natural values should be compiled, taking into account natural habitats, as well as plant and animal species, for conservation of which Natura 2000 territories have been envisaged. The aforementioned documentation should: - Present information about impact on natural values at Natura 2000 territory, located at Podlaskie province; - Present all projects and plans that in conjunction with the proposed project can cause negative impact on Natura 2000 territory; - present estimation of impact of the proposed facility on the structures and functions of Natura 2000 territory in case of high release of radioactive materials, even though measures and actions, limiting contamination potential, would be applied; - Present all possible alternative solutions, basing on their foreseen impact on Natura 2000 territories; - Present provided actions aiming at prevention, limiting or compensation of negative environmental impact; - Carry out analysis of consequences of heat, released into Lake Druksiai, impact on species of migrating birds.	Based on the complex long-term ecological studies carried out within the region of at present operating Ignalina NPP (with radius of 30 km), the forecasted impact on the environment (including the NATURA 2000 network of protected areas and the biodiversity) due to the new NPP during normal operation will not be significant. It will be the most evident in Lake Druksiai. The greatest negative impact on the ecosystem of Lake Druksiai will be due to the thermal pollution (the water cooling the reactors of the power plant will be discharged into the lake). The impacts of potential accidents on NATURA 2000 sites and their values were not considered. The legislation includes requirements for the protection of the population in case of a nuclear or radiological accident. In general, there are no measures for protection of Natura 2000 sites and their biological values in case of accidents. Throughout the world there is no relevant experience either. In an event of an accident, when radioactive materials are released into the environment, in theory, they could be transported by migratory animals (the birds more likely, because they are more agile, feed on a variety of food and can migrate over long distances). Naturally, the birds fly in a wide variety of directions. However, the assumption that the birds could transfer significant quantities of radioactive materials to the Southwest (referring to North-Eastern Poland) should be rejected. The fact is there is no scientific evidence that the land and water birds migrate in abundance from the Eastern Lithuania (e.g., surrounding of lake Druksiai) in the southwest direction so that they cross the territory of Podlaskie voivodship. Rather on the contrary, the sparse data on the water bird ringing in the western part of the former Soviet Union show that during the seasonal migrations the birds

No.	Question	Response
		migrate in a more concentrated manner over Valdai Hills, which is very rich in lakes, to the South, crossing the lake-rich eastern part of Belarus and partially the eastern part of Lithuania. Lake Druksiai is on the migration route of the water birds. Therefore, the probability that the birds could transfer significant quantities of radioactive material from Lake Druksiai or the surrounding area to North-Eastern Poland is extremely low.
6.	When talking about Chapters 6 and 7 of the Report (nuclear fuel production and transportation, as well as hazardous waste transportation), a necessity arises to extend the information on planned directions of fuel transportation for the power station. The submitted documentation only reveals that nuclear fuel will be transported to the power station by railway or auto trucks. Inter alia, information on this topic is important for identification of sources endangering the environment of the border zone (transportation of hazardous items is classified as being such a source).	Transportation of hazardous materials (including nuclear fuel) is regulated by Lithuanian legislation and regulations. Experience from almost 30 years shows that the fuel to Ignalina NPP can be transported safely. Also, fresh nuclear fuel is not so dangerous in terms of ionizing radiation. Information about transportation routes and fuel supplier will be available when reactor type and fuel supplier will be known. During the EIA phase this information is not available
7.	Besides, the main obstacle, impeding the estimation of real impact of the planned power station on the environment of Poland, is lack of detailed data on amount and spread of radioactive materials, released into the atmosphere. This problem is particularly important for identification of radiological impact internationally during normal operation of the facility, as well as in case of an accident and when applying safety standards. An entry on p. 19 of the document informs that the Environmental Impact Assessment contains a section, dedicated to assurance of nuclear safety, developed basing on models, used to perform analysis of spread of radioactive materials and exposure doses both in case of normal operation and an accident; however, this is not a sufficient piece of information.	Detailed information about releases from different types of reactors into water and air is provided in Tables 7.1-30 and 7.2-11. Dose to population caused by these releases is estimated in Table 7.10-25. Dose for Polish population will be insignificant (annual effective dose less than 0.001 mSv). Dispersion modelling and resulting impacts at distances of up to 1200 km of accidental releases are provided in Chapter 10.3.2. The distance of 1200 km covers many European countries, Poland as well.
8.	Generalizations, given in Chapter 10 of the document, stating that “during normal operation of the new nuclear power plant no transboundary radiological impact will be present”, are important for estimation of potential transboundary impact of the planned facility; however, when no detailed data on modelling of radioactive contamination spread is available, this conclusion cannot be checked. Moreover, another section of the aforementioned chapter refers to potential	Only accidental releases are estimated in Chapter 10. Impacts during normal operation and dose estimation to population according Lithuanian standard LAND 42-2007 and IAEA recommended models are provided in sections 7.10.2.2 and 8.11.1. Calculations have shown that at the distance of 8 km from NNPP annual effective dose is less than unregulated level (0.010 mSv per year). The main assumptions and results of accidental release dispersion modelling are

No.	Question	Response
	necessity of application of iodine prophylaxis to the population, residing in the range between 250 and 600 km from the power plant (basing on criterion of radioactive iodine deposition), which allows to consider that negative consequences of a potential accident might be relevant to Polish public.	provided in Chapter 10.3.2. More detailed information can be found in separate report "*Sofiev, M., Prank, M., Jalkanen, J.-P., Valkama, I., Karppinen, A. & Pietarila, H. 2008. Dispersion simulations and dose estimates for Accidental Radioactive Releases from the Planned New Nuclear Power Plant in Lithuania. – Finnish Meteorological Institute, Helsinki*". As already mentioned in the reply to Comment 3, the Lithuanian hygiene standard HN 99:2000 includes an article, indicating the criteria under which iodine prophylaxis is recommended. Based on these criteria, the distance of 250-600 km from the power plant, within which the people are recommended to apply iodine prophylaxis, has been set. However, if, following the criteria set out in IAEA documents on the need to apply iodine prophylaxis, as well as basing on the EIA reports of planned new nuclear power plants in Finland, the distance at which the need for iodine prophylaxis for children in case of a severe accident is about 100 km. In this case this conservation measure is not necessary for adults.
9.	In summary it should be stated that the lack of detail of the submitted documentation hinders from performing of thorough analysis of potential transboundary environmental impact of the object planned to be built, as well as from taking an unambiguous position on this topic.	In comparison with other EIA Reports for NPP developed in different countries, this EIA Report is comprehensive enough. It should be noted that if no significant impacts are estimated at distances 3–30 km from the NNPP in Lithuanian territory, the transboundary impacts will decrease only.

Table 3.8–3. Questions and responses discussed during the consultations with Belarusian experts.

No.	Question	Response
1.	In the EIA report the environmental impact of a virtual nuclear power plant (the type of a reactor and particular analogue of the project of the new nuclear power plant had not been defined) was considered, i.e. the question on possible impact of the NNPP on the environment of The Republic of Belarus practically has not been analyzed. Depending on type of the reactor the size of the sanitary protection zone (hereinafter referred to as SPZ) can vary (assumed 3 km), and the shortest distance from the planned sites to the border of the existing SPZ is about 1.5 km. Hence, under the most adverse conditions the planned SPZ can reach the territory of The Republic of Belarus (by the surface of Lake	The NNPP impact assessment has been carried out considering the greatest impacts caused by any of the considered reactor types. Thus the impacts of any specific reactor type will not exceed the impacts described in the EIA report. The assessment of transboundary impacts (Chapter 8) also includes the impacts that could occur in the territory of the Republic of Belarus. The NNPP site closest to the border of the Republic of Belarus, Site No. 1, is located at more than 3 km distance from the state border when measured from the assumed location of the reactor. Thus the sanitary protection zone will not reach the territory of the Republic of

No.	Question	Response
	Druksiai the distance from the facility to the state border makes less than 3 km). In this connection the conclusion that transboundary impact on the environment and public health of The Republic of Belarus will be insignificant or absent gives rise to doubts. Moreover, the EIA report notes that the NNPP power is assumed to be 3400 MW, and when the level of thermal load on Lake Druksiai from the NNPP side is above 3200 MW detrimental effect on the ecosystem of the water body becomes considerable.	Belarus. The maximum power output assessed in the EIA is 3400 MW electrical energy. The ecologically (under the most strict environmental conditions during hot summer) acceptable thermal load of 3200 $MW_{released}$ refers to thermal energy discharged to the lake and corresponds to approximately 1700 MW electrical energy produced using direct cooling system. By combining direct cooling with other cooling solutions (cooling towers) also the maximum power generation level of 3400 MW electrical energy is achievable from the environmental point of view.
2.	Potential sites for the NNPP are located within the limits of Ignalina NPP (hereinafter referred to as INPP) industrial site, where the operation of the NNPP will be carried out simultaneously with the INPP decommissioning activity. According to the assessment given in the EIA report total impact from all the objects present on the site will lead to the population exposure dose of 51.9 E-06 Sv in 2015. It can be concluded, that the NNPP commissioning will considerably exceed the combined impact from the existing facilities of INPP, estimated as 1.0E-06 Sv, from SWMSF (7.29E-06 Sv) and from operations with the spent nuclear fuel of INPP (5.82E-07 Sv).	The forecast of the total dose to population due to all nuclear facilities for 2015 is presented in Table 7.11-1. It is obvious that the dose to population during normal operation of the NNPP will be higher than doses from ISFSF and SWMSF, however the established annual dose constraint for members of the public of 0.2 mSv will not be exceeded; estimated dose will be about 4 times less than this dose constraint. Also it should be noted that the impact from NNPP has been evaluated taking conservative assumptions, as worldwide experience shows that the actual releases and caused doses to the population are 10 and more times lower.
3.	Researches, carried out in 2007 by the State Scientific Institution Joint Institute for Power and Nuclear Researches “Sosny” (National Academy of Sciences of Belarus), shown that annual effective dose of exposure of the population from the group of radionuclides ^{3}H, ^{85}Kr, ^{129}I, ^{134}Cs, ^{137}Cs, ^{135}Cs due to operations dealing with not tight spent fuel of INPP when radionuclides are transported by air, will be 10 times higher and will make 7.53E-06 Sv. Moreover, the estimation of the impact of waterborne releases due to decontamination of the dismantled equipment of the INPP second power unit in 2011 (which due to absence of data in the EIA report was roughly estimated as 8.0E-06 Sv) must be made more precise as well. In general estimation of dose stipulated by exercise of activity at several nuclear facilities on a common site bears a significant uncertainty.	Since the report of the researches made by the State Scientific Institution Joint Institute for Power and Nuclear Researches “Sosny” (National Academy of Sciences of Belarus) is not available it is quite difficult EIA to agree or disagree with the presented results. Based on the EIA Report of “Interim Storage of RBMK Spent Nuclear Fuel from Ignalina NPP Units 1 and 2; Revision 4” one year maximal effective dose to critical group member due to: - handling of all intact fuel at INPP is 7.69E-10 Sv/year; - handling of all leaking fuel at INPP is 4.15E-07 Sv/year; - operation of damaged and experimental fuel handling system is 4.75E-09 Sv/year Since operation of the NNPP is planned no earlier than 2015, the dismantling and decontamination activities at INPP up to this year are not considered in the total impact assessment.

No.	Question	Response
4.	The total annual exposure of the members of the critical group of the population due to the NNPP radioactive releases into the environment (airborne and waterborne) varies in the range from 8.74 to 50.70 µSv depending on type of a reactor, capacity and total number of units. As it was noted by the Belarus party earlier concerning the facilities planned to be constructed in connection with INPP decommissioning, the dose constraint for the population set out in Lithuania (0.2 mSv per year) considerably differs from the recommended quota for the Republic of Belarus, which makes 0.05 mSv per year. This also complicates performance of comparison of potential radiological impact on the critical group of the population of The Republic of Belarus.	The dose constraint of 0.2 mSv per year specified in Lithuanian legislation is based on international experience and IAEA recommendations. For comparison purpose it is indicated that annual effective doses to the Lithuanian inhabitants due to natural sources of ionizing radiation is 2.4-2.6 mSv in average. The average values for the doses from the main natural radiation sources are: indoor radon – 1 mSv, cosmic radiation – 0.35 mSv, construction materials indoors – 0.45 mSv. According to the available Belarus regulation "Radiation protection of population", N 122-3, 5 December 1998, clause 8, the dose limit to the population of Belarus due to ionizing radiation is 1 mSv/year (the same as in Lithuanian). However, it is not indicated exactly what dose constraint (quota) on the boundary of the sanitary protection zone of a nuclear facility (or facilities) shall be applied. It is only stated that the sum of quotas shall not exceed the dose limit. The basis for recommended quota of 0.05 mSv per year is not clear.
5.	When calculating exposure doses conditions of external exposure were considered in methodically incorrect manner. Procedure of estimation of an external exposure dose of the population (members of the critical group) in case of releases through ventilation stack of the NNPP having height of 75 m was performed applying modified factors obtained by simple multiplication of conversion factors (used for conditions of releases from INPP ventilation stack with height of 150 m at a point of the highest radionuclide fallout) by coefficient 3.4. (Regulation LAND 42:2007 referred).	The population exposure was calculated according to methodology provided in Lithuanian standard LAND 42:2007. Dose conversion factors for releases at 150 m height are provided and for lower releases the coefficients (3.4. for release height of 75 m) are indicated in this standard. Additional external exposure of population was calculated applying methodology which is provided in IAEA Safety Reports Series No. 19 "Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment".
6.	According to the forecast the exposure doses due to airborne releases varies in the range from 1.24E-06 Sv to 10.5E-06 Sv depending on a reactor type. However, not all types of reactors considered as technological alternatives have accessible initial data on the value of radionuclide release. In particular, CANDU type reactor was estimated as producing the highest exposure dose of 10.5E-06 Sv due to airborne releases, considering only four radionuclides: ^{3}H, ^{14}C, ^{85}Kr, ^{131}I. Therefore it cannot be asserted that the annual exposure dose will be within the specified limits if additional information on inventory of releases at normal operation of reactors is	The list of released radionuclides and their activities is based on freely accessible information sources (e.g. for the websites). The information provided for ABWR, AP-1000, EPR, APWR and other reactor types is very detailed. However for CANDU-6 the freely available information is not so detailed. Nevertheless, if in dose calculations for ABWR, AP-1000, EPR, APWR only the same set of radionuclides (noble cases, C-14, H-3, I-131, Co-58, Co-60, Cr-51, Mn-54 and Nb-95, which are provided for CANDU-6) are taken into account, the resulting dose will be about 99% of the total dose value. Therefore, it can be concluded that if other

No.	Question	Response
	not obtained.	released nuclides from the CANDU-6 reactor are taken into account, the dose to population will increase only about 1%. Also taking into account the comments from Lithuanian EIA relevant parties the assessment of population exposure caused by normal operation of NNPP is revised.
7.	The operation of INPP has led to considerable eutrophication of Lake Druksiai due to thermal contamination of the lake waters and wastewater discharges. The present conclusion proves to be true in the document “Final Report of 12 July 2007. EIA Program. New Nuclear Power Plant in Lithuania. Consortium Pöyry – LEI”, Section 7.1.1.6 “Water quality and biodiversity”: “Before the development of significant activities in the area, Lake Druksiai was mesotrophic. The addition of thermal and municipal wastewater releases made the lake water quality evolve to an almost eutrophic state and different ecological zones were formed in the lake”. At the same time the EIA report notices that the present condition of the environment serves as the standard for comparison and estimation of implementation of alternatives. Hence, all the analysis of environmental impact is carried out by replacing one NPP by another; thereby a priori the conclusion is made about insignificant environmental impact and about absence of necessity to assume the measures on the lake rehabilitation.	According to the Lithuanian legislation of environmental impact assessment the impacts of the proposed activity shall be compared to the “zero alternative” (non-implementation alternative). The ecology of Lake Druksiai has changed significantly due to the thermal load of Ignalina NPP and nutrient load from the municipal waste water treatment plant. Changes in the ecosystem have been so significant (e.g. species composition has changed in all trophic levels) that restoring the previous, natural stage of the lake is not possible anymore. Thus it would not be relevant from an environmental point of view, neither applicable from a legal point of view to assess the impacts of the NNPP on the lake assuming its ecological state to be as it was over 20 years ago, before Ignalina NPP was commissioned.
8.	If the Lithuanian party allows neglecting the ecological damage for the economic gain, for Belarus the construction and operation of the NNPP means continuation of the ecological damage caused by the INPP operation.	The main ecological changes were initiated by operation of the existing Ignalina NPP. The start point for impact assessment of a NNPP is the existing ecological state of the environment. The EIA Report shows that operation of the NNPP will not cause significant changes to the environment in comparison with the present state.
9.	In comments to the EIA Program of the new Lithuanian NPP the Belarus party expressed a wish to consider scenarios of waterborne transport of radioactive substances for various accident situations and at normal operation of the NPP, since under the existing hydrographic and hydrological conditions the flow of surface waters in the region of planned construction of the NPP goes from the territory of Lithuania to the territory of Belarus. However, the EIA Report has not analyzed this question. Chapters 7 and 8 give only radiological monitoring data on radionuclide content in surface and ground	Transboundary scenarios and waterborne transport (Druksiai → Prorva → Druksa → Dysna → Daugava → Gulf of Riga) modeling of radioactive substances during normal operation of the NNPP is provided in Chapter 8.11.1. Modeling of dispersion of accidental releases is provided in Chapter 10.3.2.2. The aim of accidental release modeling was to define what protective actions should be implemented in case of design basis and severe accidents. Criteria for protective actions of the public in case of a radiological or nuclear accident which are provided in HN 99:2000 (this hygiene norm also agrees with

No.	Question	Response
	waters; however, there are no results of modelling of waterborne transport of radioactive substances, including in the transboundary context.	IAEA recommendations). Waterborne transport modeling in case of accident does not provide results according to which protective actions should be defined. Impact of the surface heterogeneity, precipitation and regional lakes has been considered in the report „*Sofiev, M., Prank, M., Jalkanen, J.-P., Valkama, I., Karppinen, A. & Pietarila, H. 2008. Dispersion simulations and dose estimates for Accidental Radioactive Releases from the Planned New Nuclear Power Plant in Lithuania* " where it was concluded that "small size of the lakes, availability of other sources of fresh water and absence of intensive regular fishery in the near-plant lake allowed skipping the aquatic path of the food chain altogether – without significant discrepancies introduced into the assessment numbers". Also is should be noted, that according to calculation results and criteria for protective actions food (including fishes also) should be banned at the distances of 100-250 km; milk and drinking water should be banned at the distances of 200-600 km from NPP.
10.	It is planned to place the whole complex of objects presenting radiation and nuclear hazard in the limited territory of the INPP site, which, certainly, will lead to increase of total technogenic radiation load in this region. The problem of an estimation of potential impact from a set of nuclear facilities on a common site can be solved by the correct analysis of impacts which in methodically strict manner should consider the scheme of transfer of radioactive materials and terms of carrying out of technological operations (schedule) at different facilities together with detailed inventory of radionuclide content and activity of all facilities. In our opinion, these requirements in the EIA report have been met not in full.	It should be noted that radioactive materials and spent nuclear fuel already exist and are stored at Ignalina NPP. Existing storage facilities are quite old and the implementation of the new modern radioactive waste management and storage technologies is ongoing, which will increase the safety and decrease radiation load. Also after shutdown of Ignalina NPP Unit 2 there will be no radioactive releases which were during the normal operation of the Unit. Releases due to SNF handling are provided in the response to Comment No. 3. Therefore, the radiation load from NNPP will be added, however load from existing Ignalina NPP will decrease. The assessment of total impact shows that the resulting dose from all INPP and NNPP nuclear facilities will be about 6.01E-02 mSv/year and is less than the defined dose constraint. For each Ignalina NPP decommissioning activity separate EIA Reports are developed and inventory of radionuclides and their activities are estimated precisely. During preparation of the EIA Report of NNPP all prepared EIA Reports for INPP decommissioning activities have been considered.
11.	In the result of total impact of nuclear	Response to the listed concerns

No.	Question	Response
	facilities the hydro-geological conditions can essentially change; moreover, irreversible for Belarus social - economic (Section 8.10 does not contain any comments on impact on the Republic of Belarus) and ecological changes can arise due to the following reasons: - Temperature increase in Lake Druksiai; - Reduction of flow to the river Prorva (Subsection 8.2.2.2 (page 470-471 "Impacts on the river Prorva")); - Changes of the lake flora and fauna; - Absence of plans, programs and actions for rehabilitation of technogenic changes of Lake Druksiai; - Potential flow of surface waters towards Belarus; - Potentially increased radiation impact (up to 50.7 µSv/year); - Superfluous formation of aerosols in the region (dense fogs); - Restrictions of agricultural activity in Braslav area; - Reduction of birth rate and population in adjacent Belarus region; - Reduction of popularity of the tourist infrastructure in Vitebsk area; - Reduction of investments for development of industrial projects in connection with absence of necessary labour; - Oppressions of development of air transport in the region.	- The maximum allowable thermal load to the lake (approximately 3200 MWreleased) corresponds to the situation when two units of the Ignalina NPP were in operation. Thus the temperatures in Lake Druksiai are not expected to increase (see Section 7.1.2.6); - If the new NPP will have a higher total power generation level than the Ignalina NPP this will decrease the present discharge to the river Prorva, and thus the amount of water in the river (see Section 7.1.2.6). Calculations using recently discovered discharge values for the river Prorva show that the decrease in mean annual water discharge to the river Prorva will at a maximum (NNPP power output 3400 MW) be about 16 %, not 28 % as stated earlier in the EIA report. If the power production level will not be increased, the impacts will remain on the present level, resembling those of Ignalina NPP; - No significant changes in flora or fauna of the lake are expected (see Section 7.1 of the EIA report); - The Visaginas municipal waste water treatment plant is currently being upgraded to reduce the release of nutrients and thus the eutrophication of Lake Druksiai. Restoring the previous, natural stage of the lake is however not possible anymore (see Section 7.1); - The conclusion of the EIA report is that the locations of the current INPP cooling water inlet and outlet are optimal also for the NNPP. As the maximum thermal load to the lake can not significantly exceed the thermal load during Ignalina NPP operation due to ecological reasons no significant changes in flow of surface waters towards Belarus are expected (see Section 7.1); - The maximum annual dose to the critical group members of population, 50.7 µSv, is well below the Lithuanian health-based dose constraint of 200 µSv and will not cause any significant effects. It is very minor compared with the annual effective dose due to natural sources of radiation, which for example for Lithuanian inhabitants is 2200 µSv on average; in reality the dose to critical group members will remain significantly below 50.7 µSv, which is a very conservative estimate (see

No.	Question	Response
		Section 7.10.2.2); - The NNPP is not expected to increase the formation of fogs significantly as the NNPP thermal load to Lake Druksiai can not exceed the thermal load from Ignalina NPP significantly due to ecological reasons. In case of direct cooling local fog will be formed now and then above the warm water area in calm and cold days. In case of cooling towers local fog formation can occur during cold periods. This is not expected to spread in significant amounts to the Belarusian side and will not cause any impacts there; - The NNPP will not restrict agricultural activity in Braslav area in any way during normal operation as radiation exposure calculations show that transboundary impact due to NNPP releases is insignificant (see Section 8.11.1); - The NNPP will not have any impact on the birth rate and population in adjacent Belarusian regions as radiation exposure calculations show that transboundary impact due to NNPP releases is insignificant (see Section 8.11.1); - The NNPP will be located in an area currently occupied by the Ignalina NPP. The new plant will not change the land use in the area or cause other changes which would impact tourism in the Vitebsk area compared to the current situation; - Reduction of investments for development of industrial projects in Belarus due to absence of necessary labor is not foreseen as large amounts of workers from Belarus are not expected to participate in the new NPP project; - Air transport restrictions in the region will not change compared to the current situation as the NNPP will be located in an area currently occupied by the Ignalina NPP.
12.	According to the forecasts by the end of the NNPP operation life (60 years) depending on reactor type there will be produced from 2 700 t (reactor fuel with burn-up fraction of 65 GWd/t) to 18 000 t (reactor fuel with low burn-up fraction of 7.5 GWd/t) of spent nuclear fuel in the form of waste. The existing national strategy of spent nuclear fuel handling at the final stage of nuclear fuel cycle is not defined. Therefore the EIA Report should be also completed on the following	The EIA Report sections dealing with radioactive waste and SNF are revised taking into consideration National Radioactive Waste Management Strategy approved by the Government of the Republic of Lithuania in September 2008. This Strategy emphasizes a need to investigate alternative options of the SNF management. The disposal of in a regional or national geological repository must be analyzed together with analyzing SNF reprocessing option. Sitting of a

No.	Question	Response
	questions: - To develop the concept of storage and disposal of spent nuclear fuel, to prepare the program on its handling; - To describe directions of development of radioactive waste storage or disposal infrastructure; - In Section 8.10 "the Social - Economic Environment" to give comments on impact on The Republic of Belarus.	geological repository must be started after 2030, if no other solution will be available. Possible social-economic impacts on Belarus are provided in Section 8.10. Since radiological impact can not influence the social-economic component it is stated that radiological impact is not relevant.
13.	- In Subsection 8.11.1"Radiological Impacts" (Section 8.11"Public Health") the analysis is carried out with the perfunctory approach (Table 8.11-1), unlike in Subsection 7.10.2.2 "Radiological Impacts" for the critical group of the population of Lithuania (Table 7.10-24), the annual dose from one unit in Table 8.11-1 is higher by an order than in Table 7.10-24; besides, the dose from several sources is not specified there.	Table 7.10-24 provides the results of annual dose calculation for critical group member, which is defined in Lithuanian standard LAND 42:2007. Transboundary impacts in terms of annual dose were calculated applying methodology of IAEA Safety Reports Series No. 19 "Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment". IAEA methodology is more conservative therefore estimated annual doses are higher. Impact from several sources is estimated in Section 7.11.1. Since it is shown that dose from other sources for critical group member is at least 10 times less than from NNPP there is not point consider them in transboundary contest. Moreover, transboundary impacts from other sources are already provided in EIA Reports of these objects.
14.	In the EIA Report the unlikely event "severe accident" is incorrectly interpreted as "an impossible event" (Table 10.2.3). Actually the low probability means that an event can occur at any moment in the future, but not more often than once in 108 years per each reactor. However, such accidents can have the heaviest radiation consequences for the environment and the population of Belarus.	Wording "Impossible event" used in the Table 10.2-3 is in accordance with "Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity" (Information Publications, 2002, No. 61-297). These recommendations are not defined exactly for nuclear facilities, therefore the terminology is different. A criterion for severe accident 100 TBq release of Cs-137 was based on Finnish legislation (the same criterion is going to be introduced in Lithuanian legislation also). According to Finnish legislation the mean value of the probability of a release exceeding the target value 100 TBq of Cs-137 must be smaller than $5 \cdot 10^{-7}$ per year. Therefore, a Severe Accident of low probability is evaluated. A criterion for design basis accident is defined in Lithuanian Hygiene Standard HN 87:2002 ,,Radiation Protection in Nuclear Facilities" where is stated that "*Safety of the new designed and constructed nuclear power plant shall assure that during operation or*

No.	Question	Response
		decommissioning the dose for the members of public caused by one design basis accident shall be less than intervention level applied for protective action – sheltering, i.e. 10 mSv. The optimal means shall be foreseen in the case of beyond design basis or severe accidents to avoid heavy and sudden injuries of the general public, long-term restriction for the land and water usage and future subsequences for general public health, applying determined protective actions".
15.	The analysis of consequences of radionuclide releases for the population in case of an accident at the NNPP was performed using an example of APWR reactor (Advanced Pressurized Water Reactor, the USA) for two cases: - Design basis accident (DBA) with loss of coolant (LOCA), when containment leakage is limited to design basis leakage; - Severe accident (SA) with core damage and containment failure. For estimation of impact on the population due to the accidents a number of simplifying assumptions and allowances, which reduce reliability of the obtained conclusions about the environmental impact during the NNPP accidents, has been used. It is known that for severe (beyond design basis) accidents there are no theoretically or experimentally proved data on the magnitude of accidental release of activity into the environment available, therefore the basic share of uncertainty in the estimation of radiological consequences is related to impossibility to calculate precisely the area of containment failure and the time from the beginning of melting until damage of containment (duration of radionuclide confinement), as well as the height of releases. As a criterion of SA, conditional release of 100 TBq ($1 \cdot 10^{14}$Bq) of Cs-137 activity was assumed. Releases of some other radionuclides were scaled according to Cs-137 from their activity in APWR reactor fuel. During preparation of data on accidental releases of activity into the environment, recommendations of the US Nuclear Regulation Commission (NRC), summarizing researches on safety of light water reactors of type PWR and BWR, have been used at moderate fuel burn-up fraction of 40 GWd/t (NUREG-1495, 1995). Use of the applied NRC recommendations for reactors with burn-up of an order of 60 GWd/t, which is characteristic to the majority of the reactors	According to probabilistic risk assessment and severe accident evaluation of APWR (such assessment has been done by the reactor supplier) containment integrity is maintained more than 24 hours after onset of core damage. The time period of 24 hours is also a goal for containment performance defined in US NRC regulations and also in European Utility Requirements (EUR 2001), which includes a deterministic goal that containment integrity shall be maintained for approximately 24 hours following the onset of core damage and a probabilistic goal that the conditional containment failure probability shall be less than approximately 0.1 for the composite of core damage sequences assessed in the probabilistic risk assessment. As it was mentioned as a criterion of Severe Accident the release of 100 TBq of Cs-137 activity was assumed. In order to estimate the releases of other than Cs-137 nuclides NUREG-1495 was used. There are some uncertainties using NUREG-1495, therefore additionally fractions of initial core inventory released while containment is intact defined for EPR and will be used to show the level of uncertainties. Of course release of Cs-137 in case of Major Accident (INES level 7) will be higher, however the probability of such release will be at least by one order lower than $5 \cdot 10^{-7}$ per year. Also common approach used in IAEA recommendations and different countries states, that event with probability less than 10^{-7} per year can be not considered.

No.	Question	Response
	submitted to consideration, demands a corresponding substantiation. In this connection for the estimation of possible consequences it is expedient to use estimation criteria of SA rated as INES (International scale of nuclear events) level 6 event (from 1 000 to 10 000 TBq I-131), as well as criteria of major accident (MA) rated as INES level 7. The estimation of consequences of the NNPP accident was carried out for the DBA and SA (INES level 6). Comparison of SA and MA by radionuclide releases reveals rather essential difference. The ration between ^{137}Cs releases for SA and for MA is 1:400. There are also significant differences in values of the area of radioactive fallout, the number of population exposed to the impact of accidental releases, as well as the number of sufferers. In this connection we consider expedient to carry out an additional estimation of MA consequences.	
16.	The EIA Report presents the results of the calculation of density of ^{131}I and ^{137}Cs fallout and dose loads on the population, obtained using a method of mathematical modelling of contamination atmospheric diffusion. The SILAM model developed by the Finnish Meteorological Institute has been used; however its basic purpose is decision-making during NPP accident in a mode of real time. The model is capable to provide the reliable forecast only when a considerable quantity of data about real fields of meteorological elements (such as fields of wind speeds, temperature gradients and speeds by height, etc.) is entered. At the same time, conditions of atmospheric diffusion at release height of 100 m (within the bottom layer of the atmosphere) are substantially affected by the features of the underlying surface. There is no clarity in what detail the specificity of the local conditions around the NPP, including the water bodies and related local winds - breezes, was considered. It is also known that precipitation in the form of rain or snow is the defining factor of the increased density of contamination by cesium and iodine radioisotopes. However, it is not clear from the presented results, whether the precipitation regime of 2001-2002 was considered when estimating the territories' nature of contamination by ^{131}I and ^{137}Cs.	The roughness of the surface has been taken into account in the modeling using a standard technique which is considered sufficient when dealing with a flat and homogenous area like in this case. In the modeling each of the grid cells has its own roughness which comes from land-use. The roughness is constant in time over land and dynamic over water areas. The values for the roughness are taken from meteorological input files. In case the roughness is missing from the meteorological files, a default value is used for terrestrial areas and dynamic roughness, depending on wind speed and waves, is computed for water areas. There are several water bodies around the plant including Lake Druksiai but they are small in comparison with the regional-model resolution of 20 km. Therefore they do not need any special treatment in the model where a fraction of water surface in a grid cell is a standard parameter applied in any case. For high-resolution simulations some grid cells can appear to be mostly covered with water but then the crudeness of the dataset leads to conservative estimates of deposition since dry deposition velocity on the water surface is smaller than on other types of surface. Precipitation was included in the meteorological data used for the modeling.
17.	The system of notification about radiological	Only general information about existing

No.	Question	Response
	emergencies, which can be of transboundary type, is not transparent and complicated (Section 10.5 "Emergency Response Arrangements"), therefore the Ministry for Emergency situation of the Republic of Belarus suggests to provide direct connection by telecommunication with Vitebsk regional authority of the Ministry for Emergency situation in Vitebsk and with Braslav regional executive committee. During development of the emergency response plan, it is necessary to provide the notification of the Belarus population and the reservation of iodine tablets for them. Since interstate means of communication between Belarus and Lithuania in case of radiation accident are not established, approval of the EIA Report by Belarus party is possible only after arrangement of Settlement between the Government of the Republic of Belarus and the Government of the Lithuanian Republic on the notification about nuclear accidents, information interchange and cooperation in the field of nuclear and radiation safety.	"Emergency Response Arrangements" at Ignalina NPP is provided in the EIA Report. The similar or the same arrangements will be implemented in NNPP. Arrangements for internal and foreign announcements, communications in case of emergency situations and emergency protection actions are the subjects of international agreements of governmental institutions responsible for nuclear and radiation safety, civil defense and emergency situations. Presently, there is interdepartmental agreement between Belarusian Ministry of Natural Resources and Environmental Protection and Lithuanian Ministry of Environment according to which once in a year (one year in the territory of Belarus, next year – in Lithuania) the samples in the vicinity of Ignalina NPP are taken. Experts from both countries and representatives from Ignalina NPP participate in this sampling activity. The further interdepartmental collaboration is foreseen in the future. Moreover, on April 2008 technical protocol on radiological monitoring issues of surface waters and data exchange was signed between mentioned institutions.
18.	Besides, it is offered together with the Belarus party: - to consider the offer on carrying out the post project analysis of the declared activity, including definition of any detrimental transboundary impact on the environment and the population, as well as check of correctness of the performed forecasts; - to carry out consultations on the organization of monitoring system and implementation of supervision of the environment condition in the territory of the Republic of Belarus in the NNPP supervised area at the expense of party of origin; - after completion of the EIA report by Ministry of Natural Resources and Environmental Protection to return readily to its consideration.	Additionally estimation of uncertainties in case of Severe Accident release will be provided. Organization of monitoring system and implementation of supervision of the environmental condition in the territory of the Republic of Belarus should be solved by agreements between the governmental institution of Belarus and Lithuania.

Table 3.8–4. Questions and responses discussed during the consultations with Latvian experts.

No.	Question	Response
1.	Detailed description and considerations for the need of new	Electricity demand forecast is presented in Chapter 4.4.1. The Lithuanian Parliament approved the National Energy

No.	Question	Response
	NPP as energy supplier are missing in Chapter 1. These considerations should take into account also demand for energy in Latvia, Estonia and Poland, as well as improvements in energy efficiency that reduce the total demand for the electric energy. Report should include information about other alternatives that were considered for energy supply and more complete explanation for the particular location of the planned NPP.	Strategy by the resolution No. X-1046 of January 18, 2007 (State Journal, 2007, No. 11-430). The second part of Clause 13 of the National Energy Strategy indicates “to ensure the continuity and development of safe nuclear energy; to put into operation a new regional nuclear power plant not later than by 2015 in order to satisfy the needs of the Baltic countries and the region” (State Journal, 2007, No. 11-430). The Lithuanian Parliament, implementing the National Energy Strategy, and having regard to the European Union energy policy, in order to ensure energy supplies from different, secure, sustainable, greenhouse gas free energy sources and promote economic growth in the future, in order to protect the essential interests of the Republic of Lithuania and the national security, adopted the Law on the Nuclear Power Plant by the resolution No. X-1231 of June 28, 2007 (State Journal, 2007, No. 76-3004). The purpose and the aim of the Law on the Nuclear Power Plant is defined in Article 1: “The purpose and the aim of this law is to establish provisions for implementation of a new nuclear power plant project, to develop legal, financial and organizational preconditions for realization of a new nuclear power plant project.” The decision on a new nuclear plant construction is supplemented in Article 2: “The Parliament supports the construction of a new nuclear power plant in Lithuania” (State Journal, 2007, No. 76-3004). There are no other realistic options for the location of a new NPP in Lithuania than the proposed sites close to the existing Ignalina NPP. It is essential for the project to utilise existing land use plans and infrastructure. It should also be noted that the residents of Visaginas city and the vicinities are supportive of the impact of the new nuclear power plant on most socioeconomic spheres of life being investigated and endorse the construction of the new nuclear power plant on one of the planned sites (see Section 7.9). In addition, Lake Druksiai is the largest lake in Lithuania, which has influenced the choice to construct the existing INPP here. The construction of the new NPP will significantly reduce the socioeconomic impacts of the shutdown of INPP on the region; moreover, the present infrastructure and skilled workforce will be employed. The suitability of the chosen locations is described in detail in Section 7.
2.	Chapter about zero option has to be complemented with more complete analysis.	Environmental impact of the zero-option is presented in Chapter 4.4.2. Flue gas and green house gas emissions avoided thanks to the new NPP are estimated and the estimated emissions in the zero-option are presented in Section 7.2.2.2.
3.	Proposed two alternatives for the location of NPP are practically the same - to Druksiai Lake, and are not optimal considering its location near the Latvian border	The NNPP will be located in an area currently occupied by the Ignalina NPP. The new plant will not change the land use in the area or cause other impacts which would impact the Daugava river basin. Transboundary scenarios and waterborne transport

No.	Question	Response
	and the Daugava river basin where drinking water is taken from.	(Druksiai → Prorva → Druksa → Dysna → Daugava → Gulf of Riga) modelling of radioactive substances during normal operation of the NNPP is provided in Chapter 8.11.1. The assessment has shown that in downstream Lake Obole compartment (Belarus) the committed dose is less than the exemption level (0.010 mSv/year). Therefore the cross border transfer of new NPP effluents via hydrological pathway to Belarus and especially to Latvia is insignificant.
4.	As there is no information about the particular technology – which type of nuclear reactor and number of reactors that is planned for the new NPP, there is no specific evaluation for each type of the reactor, including risk evaluation and assessment of the impact on the environment in each case. Thus we insist on supplementing the EIA report with a detailed analysis of the impact on the environment of each type of potential reactor and also issues concerning management of spent nuclear fuel and radioactive waste management.	One of the main objectives of the EIA is to determine, if the proposed economic activity, by virtue of its nature and environmental impacts, may be allowed to be carried out at the chosen site. According to the results of the EIA the competent authority decides if the proposed economic activity is permitted on the chosen site. After this permission the next steps such as tendering process and selection of particular technologies will take place. Therefore, in the EIA Report impacts from different reactor types are evaluated. For instance, in sections 7.1 and 7.2 annual releases during normal information into water and air from ABWR, ESBWR, EPR, APWR, AP-1000, WWER, CANDU-6 are provided and resulting annual doses to population from all these reactor types are evaluated in Section 7.10. Impacts from a particular technology will not be higher than the highest impacts evaluated in the EIA Report. Risk analysis (see Chapter 10) has been performed according the Lithuanian legal act “Recommendations for Assessment of Potential Accident Risk of Proposed Economic Activity” (Information Publications, 2002, No. 61-297). The worst case scenarios for accidental releases have been defined and possible impacts were evaluated for distances up to 1200 km from the NNPP. During the operation of the NNPP the spent nuclear fuel and radioactive waste will be stored in appropriate storage facilities which are part of the NNPP. Environmental impacts from these facilities in terms of total radioactive releases from the NNPP are estimated in this EIA Report. Different SNF further management and disposal options (pool type and dry storage facilities away from the reactor, reprocessing; national/regional deep geological repository, etc) are listed in the EIA Report. However, these activities will be separate projects and own EIA procedures will implemented for them in due time.
5.	EIA report only mentions safety requirements but there are no measures of how these requirements are planned to be achieved as the type of the reactor is not known yet. There has to be ensured public participation like in EIA process when analyzing safety risks in the future.	The use of nuclear energy in general is associated with a concern for the possibility of different incidents and accidents and the environmental impacts of potential radioactive releases in such situations. For preventing accidents and limiting their consequences, high safety culture and special safety principles and regulations are required in the design and operation of nuclear power plants. Therefore, basic safety requirements are mentioned in EIA Report. These safety requirements do

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		not depend on reactor type, all reactors shall meet these requirements and justification how the reactor meets the requirements is performed in a safety analysis report. It isn't foreseen neither in Lithuanian, nor in European legislation that review of the safety analysis report requires public participation. The safety analysis report is reviewed by national authorities.
6.	In EIA report there is missing information about possible impact to the Latvian Natura 2000 territories.	Assessment of impacts on natural values of Natura 2000 territories has been carried out as part of the EIA and is presented in the EIA report in section 7.6.2. Significant impacts may occur only in the immediate vicinity of the NNPP in the vicinity of Lake Druksiai. No significant impacts caused by the NNPP alone, or together with other projects and plans, will occur in Latvian Natura 2000 areas during normal operation. Accidental impacts on NATURA 2000 have not been considered. According to the legislation protective actions are described only for humans. There are no requirements for protective actions for biodiversity. Negative environmental impacts due to normal operation of the NNPP will be prevented and mitigated because of the Lake Druksiai Natura 2000 area located next to the NNPP. No additional alternative solutions or actions aiming at prevention, limitation or compensation of negative environmental impacts on Latvian Natura 2000 areas are therefore necessary in addition to the measures applied due to the Lake Druksiai Natura 2000-area. Currently Lake Druksiai is an important wintering and resting area for migrating birds. Based on the NNPP EIA it is not possible to significantly increase the thermal load to the lake compared to the situation when both units of Ignalina NPP were in operation. Therefore no significant changes in production or species composition of the lake are expected due to the NNPP, provided the thermal load to the lake is not increased significantly. The importance of the lake for birds is partly due to the thermal load to the lake from Ignalina NPP, as this keeps parts of the lake ice-free in wintertime. Thus the NNPP will have a positive impact on migrating birdlife, especially waterfowl, if direct cooling is used, as the lake will continue to be partially ice-free in wintertime due to the thermal load from the NNPP.
7.	Instead of general management of spent nuclear fuel, EIA report should contain assessment of particular impacts on the environment of spent nuclear fuel management and interaction of NPP operation and managing spent nuclear fuel.	During the operation of the NNPP the spent nuclear fuel will be stored in appropriate storage facilities which are part of the NNPP. Environmental impacts from these facilities in terms of total radioactive releases from the NNPP are estimated in this EIA Report. Different SNF further management and disposal options (pool type and dry storage facilities away from the reactor, reprocessing; national/regional deep geological repository, etc) are listed in EIA Report. However, these activities will be separate projects and own EIA procedures will be implemented for them in due time. As the experience of the existing INPP SNF storage

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		facility and of the new ISFSF being designed shows, radiological impact of such storage facilities on the population and the environment is negligible.
8.	The risk analysis should be based on real, not optimistic construction period.	The duration of the construction work does not have an effect on the risk analysis since the identified risks may occur during operation of the NNPP.
9.	Report needs to be added with assessment of raw materials, their transporting alternatives and impact on environment, and recommendations for reducing these impacts.	Chapter 1 includes information on the consumption of raw materials during construction as well as information on the consumption of fuel, energy and chemical substances during operation. The assessment of impacts of traffic (air pollution, noise) also includes the impacts of heavy traffic, i.e. transports of raw materials. The impacts of traffic are presented in Sections 7.2.2.1, 7.9.2.3 and 7.10.2.1. At this stage it is not known from where raw materials will be obtained, and which transport routes will be utilized. The mitigation measures of the impacts of traffic are presented in Sections 7.2.3, 7.9.3.3 and 7.10.3.1.
10.	EIA report should include information about particular monitoring activities in Latvian territory. Report should include the procedure of providing monitoring results to the public. Also devices showing radiation level (monitors) are advisable in the nearby cities in public place.	Organization of a monitoring system and implementation of supervision of the environmental condition in the territory of the Republic of Latvia are the subjects of international agreements between the governmental institution of Latvia and Lithuania.
11.	There should be included assessment of locating accident posting system also in Latvia and indicated action program of competent authorities in case of accidents.	Only general information about existing "Emergency Response Arrangements" at Ignalina NPP is provided in the EIA Report. Similar or the same arrangements will be implemented in the NNPP. Arrangements for internal and foreign announcements, communications in case of emergency situations and emergency protection actions are the subject of international agreements of governmental institutions responsible for nuclear and radiation safety, civil defence and emergency situations.
12.	Chapter of the risk analysis has to include the list of the activities that will be insured in case of accidents.	Requirements for protective actions of the public in case of a radiological or nuclear accident are provided in Lithuanian hygiene norm HN 99:2000 "Protective Actions of Public in Case of Radiological or Nuclear Accident". 99:2000 provides generic intervention levels which are based on avertable dose level, which if exceeded leads to implementation of generic intervention. Avertable dose is the measure of effectiveness of protective action undertaken to protect the population against exposure to radiation (i.e., the difference between the dose to be expected without protective action and that to be expected with that). Protective actions for accidents which are considered in the EIA Report are described in Section 10.4. Emergency response arrangements that are required at nuclear power plant are described in Section 10.5.
13.	There are not mentioned any	Potential transboundary impacts during construction and

No.	Question	Response
	negative socio-economic impacts that the new NPP could generate, especially during the construction phase. Current analysis is too optimistic. Like impact on the environment from additional traffic and safety risks in Daugavpils caused by foreign workforce. And employment problems after the construction phase.	normal operation of the new nuclear power plant (NNPP) are summarized in Chapter 8. The impacts (including impact on the environment from additional traffic) are discussed more thoroughly in Chapter 7. Possible social-economic impacts on Latvia are provided in Section 8.10. The workforce will to a significant extent utilize the services of the regional main town Daugavpils on the Latvian side, which will bring significant positive socio-economic impacts to this region of Latvia. Safety risks in Daugavpils caused by foreign workforce are not expected. The NNPP project has met some resistance among the public abroad, for instance in Latvia, which indicates that the project causes concern among at least a part of the public abroad. This is at least partially an indication of a negative attitude against nuclear power as such. No significant negative socio-economic impacts are expected as the NNPP will be constructed next to an existing NPP, to which the surrounding areas have adjusted. Also Finnish experience gained during construction of Olkiluoto Unit 3 reveals the positive social-economic impacts in the region. More details can be found in TVO report http://www.tvo.fi/uploads/File/2008/EIA-supplement27082008-netti.pdf.
14.	There should be included explanation about free of charge health monitoring for all people in 30 km zone from the planned NPP, independent of the country these people inhabit.	Organization of a monitoring system and implementation of supervision of the public health in the territory of the Republic of Latvia are the subjects of international agreements between the governmental institutions of Latvia and Lithuania.
15.	Public survey should be carried out also among Latvian society not only inhabitants of Visaginas and its close surrounding.	A resident survey has been carried out in the vicinity of the NNPP sites in Lithuania. This has been considered sufficient for the purpose of exploring the opinions of the residents who may be directly impacted by the NNPP project. Inhabitants in Latvia have had the opportunity to express their views and opinions through the international public hearing procedure which has been applied in the EIA.
16.	It is recommended to expand the part of EIA report regarding the potential suppliers of the nuclear fuel (not only data from the World Nuclear Association), with respect the fact, that it is mandatory for Lithuania the rules of Euratom Supply Agency (ESA), i.e. Corfu Declaration (reference p.110 in Report, etc.).	Uranium, as any other globally traded raw material (e.g. copper), is traded in an international market where there are several international operators as described in Section 5.4.1 “Availability of nuclear fuel”. More detailed market analysis or analysis of the market restrictions are not within the scope of this EIA.
17.	It is advisable to expand the part about public opinion (in Lithuania and Latvia) (reference p. 163 etc.) par by the use of data from Eurbarometer about NPP,	Public opinion in Latvian areas nearest to the NNPP sites is discussed in Section 8.10.2. The use of data from Eurobarometer about NPP, radioactive waste etc. has not been considered necessary as it does not necessarily reflect the opinions of the inhabitants in the area closest

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	radioactive waste etc.	to the NNPP sites.
18.	It is advisable to include into Introductory part limitations under EIA program e.g. scope of the study, items, which are excluded from the study e.g. disposal of the spent fuel.	Exclusion of certain items and activities from the scope of the EIA is mentioned in relevant chapters of the EIA report. It is mentioned in the summary that decommissioning of the NNPP will undergo a separate EIA in due time.
19.	It is recommended to expand and clarify assessments of the results about the impact of sever accident, (references to p. 31, 85), where mentioned "not necessary protective measures within 3 km zone", but further – a lot of discussions about emergency measures (e.g. p. 508-517). On p. 510 there is short explanation about probabilities and uncertainties, thus for decision makers and general public, this chapter shall be expanded, more clarifications needed.	Comment is not completely clear. There is no such statement "not necessary protective measures within 3 km zone" in the EIA Report. On page 99 the targets from EUR (European Utilities Requirements document) are quoted. Off-site release Targets for Severe Accidents provided in EUR are as follows: - no Emergency Protection Action beyond 800 m from the reactor during releases from the containment; - no Delayed Action at any time beyond about 3 km from the reactor; - no Long Term Action at any distance beyond 800 m from the reactor. For achieving these targets, the release should be a few times less than 100 TBq of Cs-137. Some reactors already meet these EUR off-site release targets. However, for conservative estimations 100 TBq release of Cs-137 was assumed for severe accident. Therefore, protective measures are discussed in Table 10.4-3. As stated in the EIA Report, a value of 98 % for probability of depositions and doses means that in 2 % of cases will the estimated impact be exceeded. Given the frequency of the Design Basis Accident is <1E-04 per year, and the assessed severe accident is <5E-07 per year, the boundary of the consequences identified in the EIA Report is ~1E-06/ and 1E-09/ y respectively, i.e. extremely low likelihood. Section 10.4 contains all relevant information to show what protective actions of public, according to what criteria might be needed in case of Design Basis Accident and Severe Accident at new NPP.
20.	The EIA report shall include additional monitoring data regarding the radioactivity in ground water, not only in the vicinity of NPP, but also in other sampling points (e.g. points 1453, 1454, 1455 etc., (references to p. 164-165).	On the scheme (see Figure 7.1–18) the groundwater observation network, which existed in different periods starting from 1987, around the INPP is shown. In 1987 there were about 30 observation wells with depth up to 10 m, including Lake Druksiai catchment territory in Belarus and Latvia. After the collapse of Soviet Union about 15 observation wells remain in Lithuanian territory, however observations in Latvian and Belarusian territory have been cancelled. Information presented in EIA Report about radioactivity in groundwater is based on recently issued "Radiation Monitoring at INPP Region in 2007" (INPP Report ПТОот-0545-15, 2008) and scientific research study „The assessment of radioecological and ecotoxicological state of Lake Druksiai to collect information about the radionuclides activity in bottom sediments, flora and fauna of Lake

No.	Question	Response
		Druksiai and in flora of the vicinity of Ignalina NPP and to measure their activity during the operation, 2007".
21.	To provide supplementary information about studies (situation) for the location 2 with respect to the tectonic (references to the p. 274, 432 and 438), taking into considerations, that investigations already started.	The separate project "Site evaluation of potential sites for the new NPP" is going to be initiated. The aim of this separate project is to evaluate the suitability of potential sites for construction of the new NPP according to IAEA Safety Requirements NS-R-3 „Site evaluation for nuclear installations". During this evaluation a detailed description of the sites will be prepared and the set of parameters (soil characteristics, seismicity, ambient temperatures, etc.) important for designing will be identified. Despite the fact that Site No. 2 has been investigated less than Site No. 1 the information is sufficient for environmental impact assessment. Further on the safety analysis report on the NNPP will contain analysis on how the environment of the sites (geological and seismic conditions, meteorological characteristics, human activity and etc.) can affect the safety of the NNPP.
22.	To provide explanation, why recommendations regarding the radioactive waste management (reference to p. 43) for joint activities with respect of the "old" INPP and new NPP are not considered during the preparation of the radioactive waste management plan for the Lithuania.	Radioactive waste management is described in Chapter 6.2.2. Radioactive waste of the new NPP will be managed, stored and disposed of in accordance with the Radioactive Waste Management Strategy, approved by the resolution No. 860 of the Government of the Republic of Lithuania of September 3, 2008 (State Journal, 2008, No. 105-4019). At Ignalina NPP the Cement Solidification Facility for liquid radioactive waste solidification has been commissioned, the possibility (after completion of solidification of all foreseen INPP liquid radioactive waste) of later utilization of this Cement Solidification Facility and the Interim Storage Facility for the new NPP liquid radioactive waste solidification and storage as well as other joint activities will be considered during the designing of the new NPP.
23.	The Latvian Ministry of the Environment supports the question of compensation mechanism raised by Daugavpils District Council, regarding electricity provision on reduced tariffs, health insurances and health monitoring. Developer should include development of infrastructure (road) in the Latvian territory near the planned NPP.	The question of compensation mechanism raised by Daugavpils District Council, regarding electricity provision on reduced tariffs, health insurances, health monitoring and development of infrastructure (road) in the Latvian territory, is the subject of international agreements between the governmental institutions of Latvia and Lithuania.

4 ALTERNATIVES

The proposed economic activity is the construction of a new nuclear power plant (NNPP) in the vicinity of the existing Ignalina NPP. The total electricity production capacity of the new NPP will not exceed 3 400 MW. The new NPP will consist of two to five units depending on the plant size and reactor type to be chosen.

In this chapter the alternatives for executing the proposed economic activity are presented and compared. However, also the options excluded from the investigation as well as the non-implementation alternative are presented. The evaluated alternatives include the following:

- location alternatives;
- cooling alternatives (direct and indirect (cooling towers) cooling; alternative scenarios for electricity production levels; location of the cooling water inlet and outlet channels);
- technological alternatives (types of reactors);
- non-implementation alternative;
- options excluded from the investigation.

4.1 LOCATION ALTERNATIVES

There are two options for the location of the new NPP. The alternative sites are located in the territory of the existing Ignalina NPP (Figure 4.1-1):

- Site No. 1: location east of the Ignalina NPP unit 2,
- Site No. 2: location west of the switchyard.

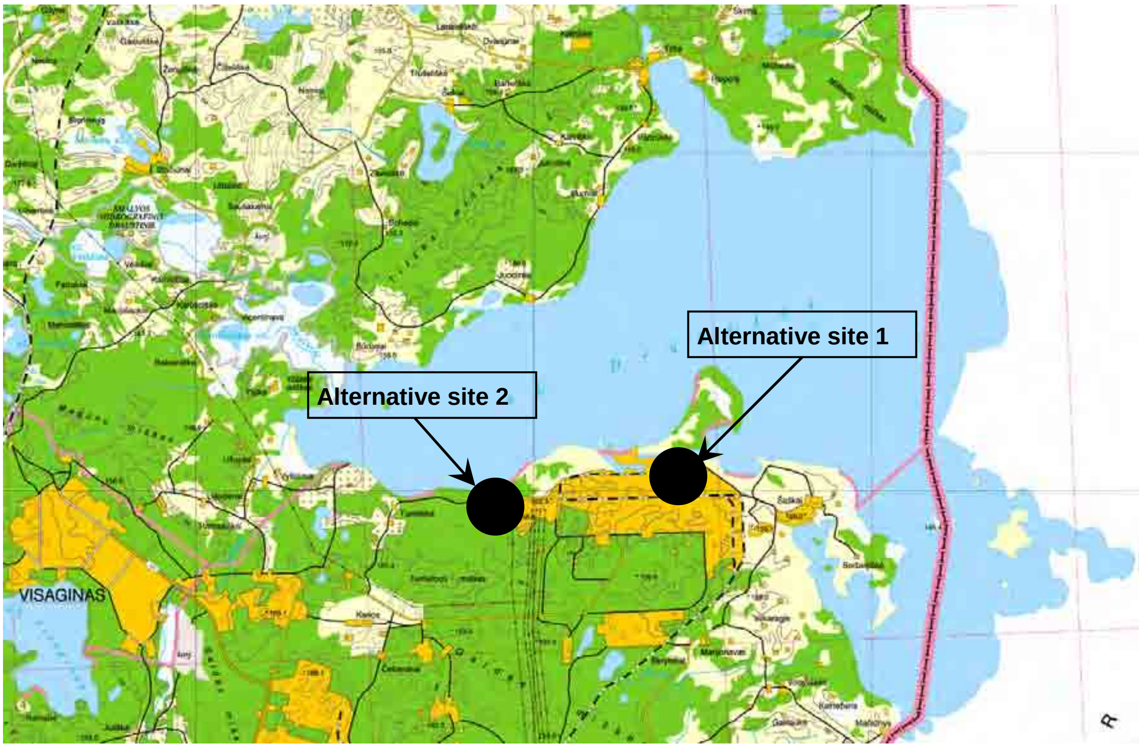


Figure 4.1-1. Location of Site alternatives No. 1 and No. 2.

The construction of the nuclear facilities in the territory was started in 1974. Ignalina NPP has been in operation since 1983, using Lake Druksiai for cooling. The first INPP unit was shut down in 2004. In 2009 also the second INPP unit will be closed. The decommissioning process will continue at least until 2030. Therefore the purpose of the site, to produce electricity by nuclear power, will remain the same also after the new nuclear power plant is constructed.

The current territory of the INPP is the only territory in the Republic of Lithuania, with existing electricity transmission, cooling water, transportation roads and auxiliary facilities, which are necessary for the operation of the nuclear power plant. In addition there are other nuclear facilities planned as well as under construction including the facilities for radioactive waste management and disposal facilities.

It is also planned to carry out an ecogeological study (environmental audit) of these alternative sites. This study will seek to identify the consequences of the activities that were exercised previously on the sites, i.e. the soil contamination, underground obstacles, etc. (in particular in case of the alternative site No. 1, where the construction of Unit 3 of Ignalina NPP was started). The results of this study will be important for the determination of the value of the sites, as well as for the planning of actions of the project risk management.

4.2 COOLING ALTERNATIVES

4.2.1 Inlet and outlet locations

Three alternative inlet and two alternative outlet locations have been studied with a 3D-flow model. Alternative inlet locations were the present location, a location about 2 km to the west from the present location and a tunnel from the deep part of the lake. Alternative outlet locations were the present outlet location in the middle of the lake and an outlet to a bay in the southern part of the lake. Additionally, an outlet alternative where the cooling water flow was divided into these two outlets was studied. The locations are shown in Figure 4.2-1.

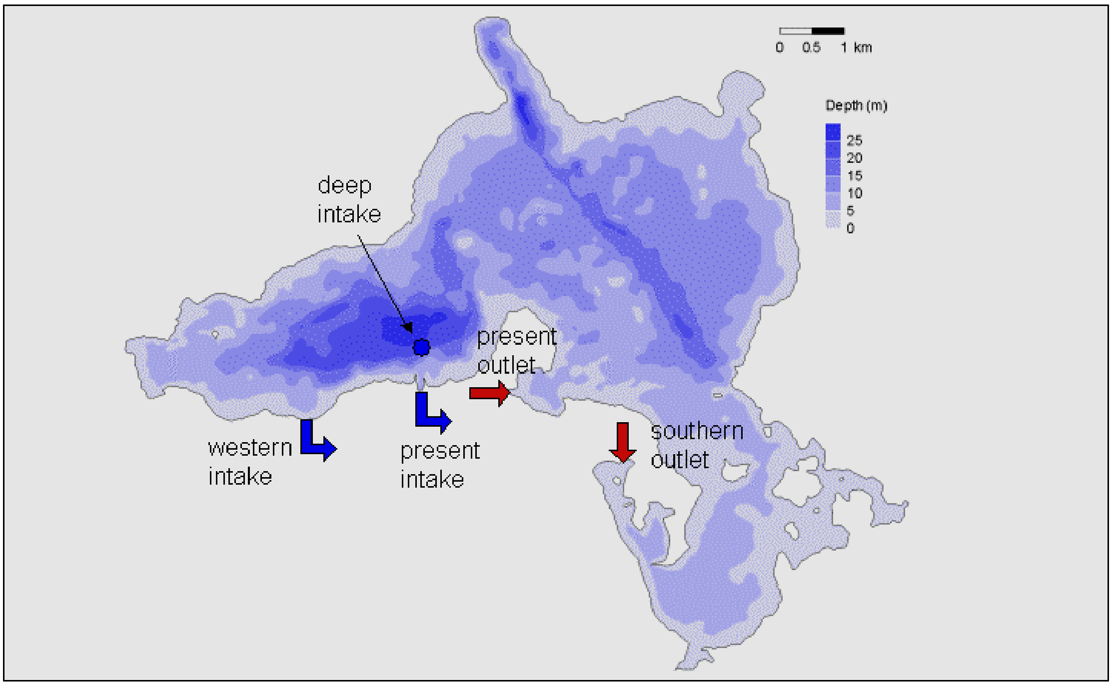


Figure 4.2-1. Alternative inlet and outlet locations.

Present inlet and present outlet were chosen for modelling since the existing infrastructure would be adequate also for the new NPP. Additional locations were chosen based on expert estimate on how to assess in the modelling as wide a variety of thermal impacts as possible.

The deep inlet option was selected to assess the possible advantages of obtaining cooler water from the deep water layers. The western inlet is located close to the alternative site No. 2 and additionally the distance to the outlet locations is longer than from the present inlet. It was estimated that longer distance between inlet and outlet might give a different thermal impact. Furthermore, it might decrease recirculation of cooling water which in turn would benefit electricity production. Also the southern alternative was selected since it would increase the distance between the inlet and outlet areas. The divided alternative was selected to assess the possible benefits of dividing the thermal load to two areas.

To investigate the effect of NNPP inlet and outlet locations on lake temperatures, six alternative NNPP inlet and outlet location combinations were computed (see Section 7.1.2 for modelling description and results).

4.2.2 Cooling water systems

The main duty of a power plant cooling system is to condense low pressure steam exiting from a steam turbine. The lower the cooling fluid temperature is, the greater the condenser vacuum and efficiency of the plant are. Selection of the cooling system has a substantial effect on this. Finding the most suitable system requires examination of many parameters related to equipment and plant location.

Once-through system (OTC), later referred as direct cooling, and wet cooling tower (WCT) are considered as wet cooling methods due to the fact that both use water as the primary cooling substance. Both systems have a high cooling efficiency and therefore they are the most commonly used cooling systems in power plants for energy production. Wet cooling tower can be either natural or forced draft type. Dry cooling systems can be direct, such as air-cooled condenser (ACC), which uses air as a primary cooling substance or indirect, such as Heller, where water is used as a primary and air as a secondary coolant. In the dry-cooling systems the cooling efficiency is lower than in the wet cooling systems but also the demand of water is lower. In the sections below, cooling systems are examined in more detail.

4.2.2.1 Direct cooling

In direct cooling the cooling water is taken e.g. from a lake or a sea, led through screening and directed to the condenser. Also an indirect construction of a direct cooling system is possible, where the primary cooling water (from the water base) is led through a separate heat exchanger which cools down the secondary (closed) cooling water flow that is used at the condenser. The primary cooling water will be returned to its origin.

The cooling water has to be pumped from the water base, which causes some power demand, but as there are no other power demands as fans, the power consumption is lower when compared with WCT. The investment cost of a direct cooling system is typically low, since no tower has to be constructed. However, it is essential that there is a water system with adequate water resources in the vicinity of the NPP.

4.2.2.2 Wet cooling tower

In WCT the cooling water is led to a cooling tower by spraying. Large amount of small droplets form a vast heat transfer area between water and cool air. The latent heat absorbed to the evaporating water, together with convection and radiation, creates the cooling effect. After contact with the air the cooled water trickles down the fill structure to a basin from where it is pumped back to the condenser.

The cooling tower can be either natural or forced draft type. Natural draft tower utilizes buoyancy via a tall chimney to create a current of air through the tower. Warm moist air in the tower is less dense than drier outside air at the same pressure. The air naturally rises due to the density difference, which creates a current trough the tower. A forced draft tower utilizes power driven fan motors to force air through the tower. A natural draft type cooling tower is typically a large construction, but does not require power to operate blowing fans. Forced draft cooling tower is significantly smaller in size, but requires electricity.

Especially in cool and moist climate conditions a visible plume is formed above the tower due to saturation of the exiting air. At freezing conditions special attention must be paid to the operation of the tower to avoid icing, as it reduces the heat transfer efficiency and might break the structures of the cooling tower. Anti-fouling chemicals have to be added to the water circulating within the cooling tower.

Wet cooling towers can also be used as a part of the direct cooling system to decrease thermal discharge to water base. With this solution, condenser cooling water discharge is led (entirely or partly) through this so called "helper cooler" which cools down the exiting water. This arrangement basically moves a part of the thermal discharge from water base to atmosphere.

4.2.2.3 Dry cooling methods

Specific features of an air-cooled condenser (ACC) and Heller system are insignificant make-up water consumption but also rather ineffective cooling. However, under circumstances where water is not available these cooling methods can be a reasonable solution despite the greater investment costs and the demand of large area.

ACC uses air as the cooling substance. The low-pressure steam from the turbine is led to the condenser, which consists of numerous finned tubes, usually mounted to an A-form. The steam condenses to water inside the tubes and cools down to the design temperature. The cooling occurs with convection and radiation. The air circulates through the condenser by fans, which require electricity. Because of the large diameter of the low pressure steam pipelines, the condenser must be located near the steam turbine. Due to relatively low heat transfer efficiency, ACC also requires a large area to be placed.

Heller is an indirect dry cooling method. There's a closed circulation between the condenser and the dry cooling tower whose structure is very similar to ACC's. The condenser is jet type which sprays the cooled water directly to the boiler water circulation. Therefore the cooling water has to be demineralised water. As the condenser is at vacuum, the cooled water from the tower is expanded at a regeneration turbine which regenerates a part of the pumping power needed for cooling water circulation.

4.2.2.4 Hybrid cooling tower

Hybrid cooling tower combines the features of both wet and dry cooling. The construction of a hybrid tower may vary significantly along the various manufacturers. The basic idea is, however, that the wet cooling part is located at the bottom of the tower and the dry cooling at the top. Typically the basic design criteria are to diminish the use of water under certain conditions and prevent the formation of a plume.

4.2.2.5 Cooling system comparison

The most essential factor in the cooling system selection process is the availability of a sufficiently large body of water. Other aspects include e.g. the effects on the plant efficiency and availability of required land area.

In the following Table 4.2–1 the examined cooling systems are roughly compared with each other. The forced draft wet cooling tower is set as a base system (evaluation factor 1 for all parameters) to which the other systems are compared.

Table 4.2–1. Relative comparison of the cooling systems.

Parameter	WCT[1]	WTC^{2}_{nat}	DC[3]	ACC[4]	Heller[5]	Hybr.[6]
Investment costs	1	>1	<1	>1	>1	>1
Internal power consumption	1	<1	<1	>1	>1	~1
Water demand	1	~1	>1	0*	<1	<1
Chemical additions	1	1	<1	<1	<1	~1
Condenser pressure	1	1	<1	>1	>1	~1
Noise	1	<1	<1	>1	>1	~1
Plume	1	1**	<1	0	0	0
Required area	1	>1	<1	>1	>1	>1

* If finned tubes are not sprayed (in any case <1)
** The amount of plume is the same than with mechanical draft tower, but it's discharged at a higher level (less possible negative effects)
[1] WCT – Wet cooling tower; forced draft
[2] WCT_{nat} – Wet cooling tower; natural draft
[3] DC – Direct cooling system
[4] ACC – Dry cooling system; air-cooled condenser
[5] Heller – Dry cooling system; heller
[6] Hybr. – Hybrid tower

The direct cooling system is the most efficient cooling system but it requires a water system with large capacity. Its advantages are the usually lower investment costs and higher plant efficiency. In the once-trough cooling the receiving water body acts as a heat sink from where the heat is transferred to air by evaporation. The discharge of heated water can have negative environmental impacts in the receiving water body. However, in once-trough cooling the cooling water does not necessarily need any other treatment than mechanical removal of larger solids whereas the cooling towers usually need treatment for biofouling, scaling and suspended matter, with acceptable biocides, antiscalants, and dispersants, respectively.

Wet cooling tower is the commonly used system at locations with finite water resources. It is the second most efficient cooling system after the once-trough system. It also has higher investment costs. Its power consumption as well as demand for area depend on the design type. The natural draft towers consume less energy but demand more space than the forced draft towers. A common feature of the wet cooling towers is the formation of a visible plume especially during colder months. Since most of the heat is evaporated to the atmosphere and not discharged to the water system, the effects on the surrounding water system remain smaller than with the direct cooling.

With the helper cooler solution the thermal discharge to a water base can be decreased. The efficiency of this system is highly dependent on the temperature difference between air (wet bulb) and cooling water discharge. As long as the air wet bulb temperature is 5 degrees or less lower than the exiting cooling water, helper cooler has no significant effect. E.g. with low cooling water temperatures, air wet bulb temperature must be zero or less to justify the helper cooler. With cooler air (or warmer cooling water discharge) the effect can be reasonable. The helper cooler can be a good solution for a secondary supporting cooling system, which can be used only during the warmest summer months.

The dry cooling systems are not regularly used as a primary cooling system in large (> 1000 MW) power plants since they demand a relatively large area (up to ten times as large as for wet cooling towers) and decrease the plant efficiency significantly. The electricity demand is also higher than in direct cooling due to the fans, which are required for air circulation. The investment costs of dry cooling systems are substantially higher than those for wet cooling. Also, the dry tower system alone can be unable to produce the needed performance required during periods of ambient high temperature. The advantage of the dry cooling systems is that they barely consume water at all, thus there are typically no evaporation losses. Since it does not produce any thermal discharges it does not cause any heat impacts on the surrounding water systems.

In conditions when water can be a limiting factor for some time periods it can be favourable to combine both dry and wet cooling methods. It is possible to use separate wet and dry towers or to incorporate both wet and dry cooling sections in the same tower design (hybrid). The cooling system can be operated based on the prevailing conditions. When sufficient amounts of water are available the dry cooling, which consumes more electricity, would be turned off and heat removal would rely on wet towers. During times of limited water resources the heat or, depending of the design, some proportion of it would be removed by the dry towers.

For comparison of the different cooling systems some central parameters for a plant with a gross production of 1700 MW are presented (Table 4.2–2). The gross production is set to be 1700 MW for a plant using once-trough cooling. The gross production for the other cooling systems is calculated by taking into account the efficiency losses due to the higher condenser pressure. The net production is calculated by deducting the internal consumption of the cooling systems (pumps, fans etc.).

Table 4.2–2. Indicative comparison of the different cooling systems.

Parameter	DC[1]	WCT (nf)[2]	WCT (forced)[3]	ACC[4]	Hybr.[5]
Electricity production (gross, MWe)	1 700	1680	1680	1642	1680
Electricity production (nett, MWe)	1678	1663	1646	1614	1644
Condenser pressure (bar)	0.032	0.04	0.04	0.062	0.04
Cooling water flow (m^3/s)	80	70	70	0	70
Evaporation (m^3/s)	0.75	0.75	0.75	0	0.73
Discharge to lake (m^3/s)	80	0.25	0.25	0	0.24
Required area (m^2)	na*	23 000	15 000	33 000	22 000

[1]DC – Direct cooling system
[2]WTC (nf) – Wet cooling tower; natural draft
[3]WTC (forced) – Wet cooling tower; forced draft
[4]DCS (ACC) – Dry cooling system; air-cooled condenser
[5]Hybr. – Hybrid tower
*Not applicable

The values clearly indicate that the direct cooling system is the best option when it comes to the electricity production. It also consumes less water compared to the wet cooling towers. The dry cooling option is clearly the most consuming system in terms of electricity and area. Wet cooling towers consume more energy than direct cooling, but are still significantly more efficient than the dry options. The estimated values for the hybrid tower are strongly dependent on the design and the amount of heat rejected by the dry cooling system. The ecological and hydrological effects and criteria affecting the selection of the cooling system are further discussed in Section 7.1.

4.3 TECHNOLOGICAL ALTERNATIVES FOR NUCLEAR POWER REACTORS

Nuclear power plants were first developed during the 1950's and 1960's. In the early days several different types were studied and built, but only a few designs ended up in wide commercial use. The first test and prototype reactors represent the first generation of nuclear power plants, created for the development of nuclear power in industry today. Most of the current operating nuclear power plants are Generation II (including the existing Ignalina NPP), constructed in the 1970's having evolved from Generation I technologies. These units have been found to be safe and reliable, but are being superseded by better designs.

Generation III reactors were developed during the later 1980s and 1990s. Generation III+ refers to the most advanced new power plant types currently available, remaining based upon the original concepts for fuel and plant design, operating at modest temperatures and pressures. Generation IV units are at the concept/ early development stage and are not expected to be viable as a commercial offering before 2015–2020. Their operating principles are very different, generally operating at high temperatures (and improved efficiency), requiring new fuels and special coolants.

All current marketed commercial nuclear power reactors use water to remove heat from the reactor core. Most of the nuclear reactors around the world are so-called Light-Water Reactors (PWR, BWR). In addition to light-water reactors, there are heavy-water moderated reactors (PHWR). Other less common reactors in commercial use include graphite moderated and gas cooled tube reactors. Ignalina nuclear power station in Lithuania currently employs the RBMK-1500, a water-cooled and graphite-moderated reactor.

Generation III (Advanced LWR) and III+ (Evolutionary Designs) have a number of characteristic features for future nuclear power plant programs:

- A standardised design for each type to expedite licensing, reduce capital cost and construction time;
- A simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets;
- Higher availability and longer operating life – typically 60 years (cf. 30–40 years for present designs);
- Reduced possibility of core melt accidents by design and additional protection systems;
- Resistance to serious damage that would allow radiological release from external impact and terrorist activity;
- Higher burn up fuel to reduce fuel use and the amount of radioactive waste
- Special "burnable" absorbers to extend fuel life.

The greatest enhancement from Generation II designs is that many incorporate passive or inherent safety features which require fewer or no active controls or urgent operator intervention to avoid accidents in the event of a malfunction. They are not only intrinsically safer, but also have optimised features giving higher availability and better economics than their predecessors.

The possible technical alternatives for nuclear reactors being considered for the new nuclear power plant in Lithuania are all generation III or III+ reactors of the following types:

- pressurized water reactor (PWR);
- boiling water reactor (BWR);
- pressurized heavy water reactor (PHWR).

Specific details of Generation III design alternatives for construction in Lithuania are provided in Section 5.2.

Figure 4.3-1 shows the evolution of nuclear power.

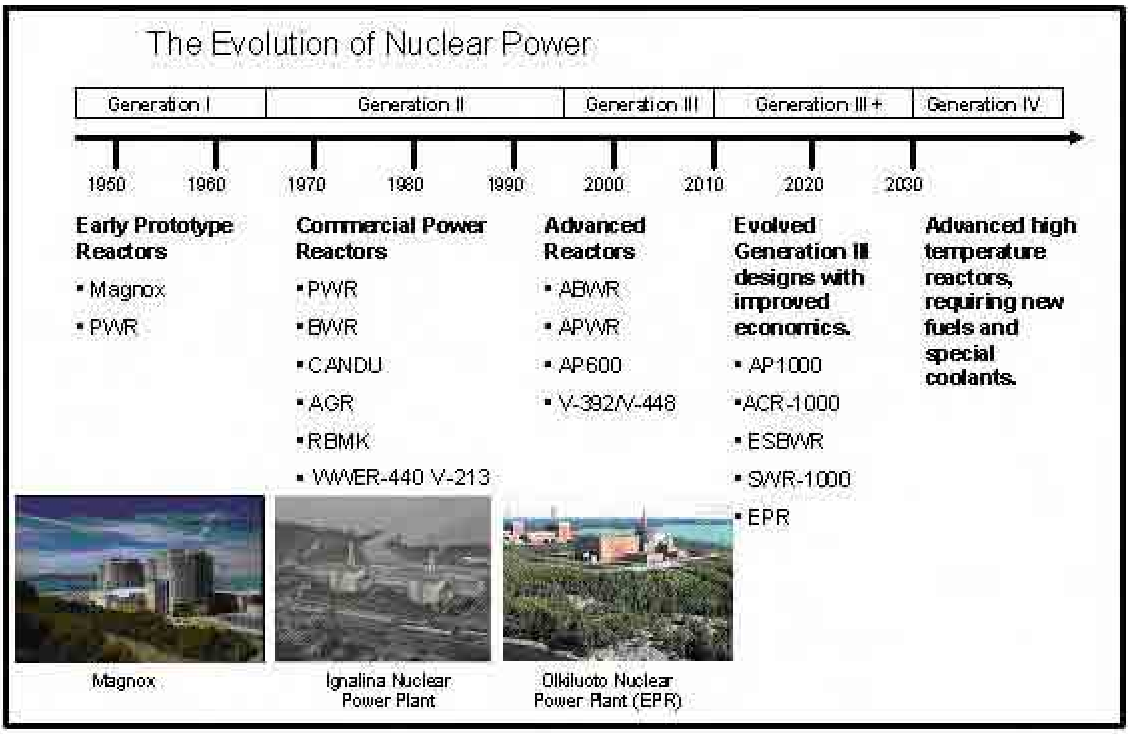


Figure 4.3-1. The evolution of nuclear power.

4.4 NON-IMPLEMENTATION

According to a so called non-implementation, or zero option, no new nuclear power plant unit will be constructed in Lithuania. In this case the supply of energy from diverse, secure, sustainable energy sources which do not emit greenhouse gases and other pollutants will not be secured and the country's energy security will not be ensured.

4.4.1 Electricity demand forecast

Since 2000 the Lithuanian gross domestic product (GDP) has been growing very fast – on average by 7.9 % per year. It is foreseen that after temporary decrease in economy the rapid rate of economic growth will persist in the coming two decades. In the National Energy Strategy approved by the Lithuanian Parliament in 2007 (*State Journal, 2007, No. 11-430*) three possible economic development scenarios have been chosen for future forecasts: 1) fast economic growth scenario (the annual GDP rate of 6 % during the period from 2005 to 2025), 2) basic scenario (the GDP growth rate of 4.5 %), and 3) slow economic growth scenario (the annual GDP rate of 4 %). The basic scenario is based on the most likely economic development trends, assuming that the Lithuanian economy will attain the current economic level of the EU states within the next 15 years.

Fast growth of the national economy is one of the most important factors that increases energy consumption, in particular, electricity demand. During the period of 2000–2006 final electricity consumption by end user grew by 5.3 % per year. However, gross electricity consumption increased only by 3 % per year because the power plants' own needs in 2006 were 27 % lower than the 2000 level due to the closure of Unit 1 at Ignalina NPP, and because electricity transmission and distribution losses also decreased during that period.

Although electricity consumption over the period of 2000–2006 showed the most rapid increase compared to the consumption of other energy forms, Lithuania is lagging considerably behind developed European countries in terms of the comparative indicator of final electricity consumption per capita by economic sector (2336 kWh per capita). In 2005, the average electricity consumption per capita in the EU-27 countries was 2.4 times as high as in Lithuania (in Finland 6.6 times, in Germany 2.7 times, even in new member states about 2 times). Therefore, the energy demand forecast was based on the assumption that the modernization of the Lithuanian economy would require the rapid growth of the electricity demand.

An increase in electricity demand will be considerably influenced by the dynamics of macroeconomic indicators (GDP growth, structure of branches of the economy, etc.), rising fuel and energy prices, consumer response to rising income and higher energy prices, energy efficiency enhancement and other factors. With a view to estimate the uncertainty of economic growth and other factors, uncertainty analysis methodology was applied for forecasting in the National Energy Strategy (*State Journal, 2007, No. 11-430*). It allows analysing changes in energy consumption in economic sectors, taking into account interrelationship between the factors determining consumption, as well as assessing tendencies of their changes.

In the National Energy Strategy (*State Journal, 2007, No. 11-430*), projections of electricity demand (net electricity generation), presented in Figure 4.4-1, take into account final energy consumption, electricity consumption by energy transformation system (including needs of petroleum refinery, oil extraction, heat plants and other energy sector activities) and losses of electricity transmission and distribution. As is shown in Figure 4.4-1, by the end of planning period electricity generation for the country's internal demand in the fast economic growth scenario will increase 2 times, basic scenario – 1.8 times, and slow economic growth scenario – 1.5 times.

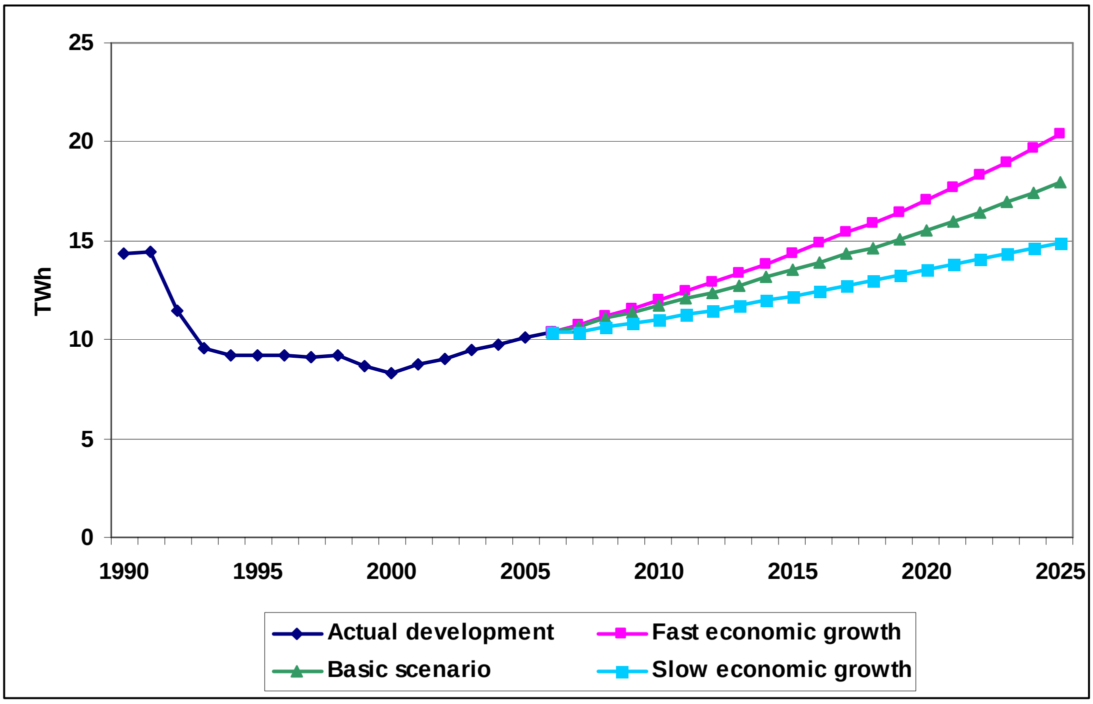


Figure 4.4-1. Electricity demand by scenario.

Disaggregated forecast of electricity demand for the basic scenario by sector is presented in Figure 4.4-2. According to the forecast, the final electricity demand in the branches of economy would reach and exceed the level of 1990 by the year 2017.

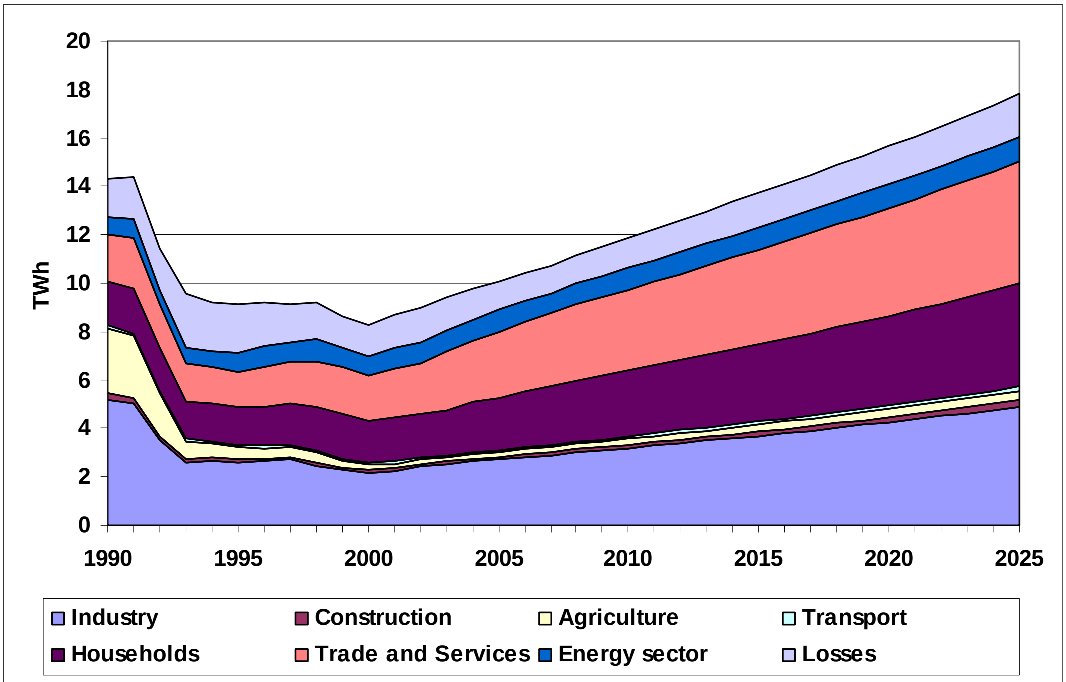


Figure 4.4-2. Electricity demand by sector.

Currently, the Ignalina NPP is dominating in electricity generation – in 2007 its share was 72.6 %. The share of electricity from renewable sources increased up to 4.4 %, and the rest (13 %) was generated by the power plants using natural gas and heavy fuel oil. Lithuania will comply with the EU requirements on the use of renewable energy resources for generating electricity. Renewable energy resources like wind power plants, small hydropower plants and biofuel burning CHP plants being constructed within the next few years will account for over 7 % in the total electricity generation balance in 2010. In 2025 their contribution should increase up to 10 %. Thus, after the closure of the Ignalina NPP more than 90 % of electricity will come from fossil fuels, unless a new nuclear power plant is constructed (National Energy Strategy (*State Journal, 2007, No. 11-430*)). In the analysed zero-option, it is assumed that the amount of electricity equal to the production of the new NPP would be partly produced in Lithuania in thermal power plants and part of it would be imported.

Evaluation of the economic effectiveness of utilisation of various energy resources, construction of new energy generating capacities, modernization of existing energy technologies and implementation of appropriate environmental protection measures causes a complex problem, which should be solved by analysing future development of the country's energy sector during a comparatively long period of time. In addition, the Latvian and Estonian energy system development, as well as new opportunities for the import of electricity due to the integration into the Scandinavian electricity market and due to the possible interchange of electricity flows between the UCTE (Union for the Co-ordination of Transmission of Electricity) System and the Baltic electricity market (*IAEA TECDOC Series No. 1541, 2007*) shall be taken into account.

Dependence on the energy import from Russia and the risk of energy supply disruptions will increase significantly. The cost of electricity production will increase dramatically – more than three times due to very high prices for gas and oil and comparatively low efficiency of existing generating units at the Lithuanian TPP. In addition, the replacement of nuclear energy by fossil fuel will significantly increase CO_2 emissions.

The Lithuanian Parliament approved the National Energy Strategy by the resolution No. X-1046 of January 18, 2007 (*State Journal, 2007, No. 11-430*). The second part of Clause 13 of the National Energy Strategy indicates "to ensure the continuity and development of safe nuclear energy; to put into operation a new regional nuclear power plant not later than by 2015 in order to satisfy the needs of the Baltic countries and the region" (*State Journal, 2007, No. 11-430*).

The Lithuanian Parliament, implementing the National Energy Strategy, and having regard to the European Union energy policy, in order to ensure energy supplies from different, secure, sustainable, greenhouse gas free energy sources and promote economic growth in the future, in order to protect the essential interests of the Republic of Lithuania and the national security adopted the Law on the Nuclear Power Plant by the resolution No. X-1231 of June 28, 2007 (*State Journal, 2007, No. 76-3004*). The purpose and the aim of the Law on the Nuclear Power Plant is defined in Article 1: "The purpose and the aim of this law is to establish provisions for implementation of a new nuclear power plant project, to develop legal, financial and organizational preconditions for realization of a new nuclear power plant project." The decision on a new nuclear plant construction is supplemented in Article 2: "The Parliament supports the construction of a new nuclear power plant in Lithuania" (*State Journal, 2007, No. 76-3004*).

4.4.2 Environmental impact of zero-option

In a case when future electricity generation is based mostly on fossil fuel, existing units at the Lithuanian TPP should produce more than 50 % of electricity necessary to meet the country's internal demand. In addition, the construction of new CHP plants and combined cycle gas turbine units is required. Natural gas will become the major source of primary energy. As there are targets in the Lithuanian Energy Strategy to increase the use of biomass, also biomass-based electricity production is assumed to be included in the zero-option. Imported electricity is assumed to be produced in thermal power plants using coal and oil as a fuel and in hydro and nuclear power plants as well.

Flue gas and green house gas emissions avoided thanks to the new NPP are estimated and the estimated emissions in the zero-option are presented in Section 7.2.2.2.

4.5 OPTIONS EXCLUDED FROM THE INVESTIGATION

Alternative locations in Lithuania

There are no other realistic options for the location of a new nuclear power plant in Lithuania than the proposed sites close to the existing Ignalina NPP. It is essential for the project to utilise existing land use plans and infrastructure. It should also be noted that the residents of the Visaginas city and the vicinities are supportive of the impact of the new nuclear power plant on the most socio-economic spheres of life being investigated and endorse the construction of the new nuclear power plant on one of the planned sites (see Section 7.9). In addition, Lake Druksiai is the largest lake in Lithuania, which has influenced the choice to construct the existing INPP here. The construction of the new NPP will significantly reduce the socioeconomic impacts of the shutdown of INPP on the region; moreover, the present infrastructure and skilled workforce will be employed. The suitability of the chosen locations is described more in detail in Section 4.1.

Energy saving

The organisation responsible for the project, Visagino atomine elektrine, UAB, does not have means to save energy in Lithuania so that the new nuclear power plant or corresponding amount of electricity would not be needed. Thus energy saving has not been investigated as an alternative to the new NPP.

Alternative ways to produce energy

Other options to generate the electricity would be by using other energy sources such as oil products, coal, natural gas, peat, biofuels, hydropower or wind power. However, the nuclear power plant project organisation, and later project company, has been established for constructing and operating a new nuclear power plant in Lithuania and therefore does not have a mandate or possibilities to construct any other kind of power plants. If another company or organisation should begin to develop such power plants, the environmental impacts of them would be assessed as a part of those projects. The purpose and justification of the nuclear power plant project is described more in detail in Chapter 1.

Thus impacts of alternative forms of electricity production in Lithuania have not been assessed in this EIA process. However, the differences between the impacts from other energy generating sources and nuclear power plants on air quality, the emissions of greenhouse gases and other pollutants caused by producing the corresponding amount of energy with other fuels are demonstrated in Section 7.2.2.

5 TECHNOLOGICAL PROCESSES

5.1 OPERATIONAL PRINCIPLES OF A NUCLEAR POWER PLANT

5.1.1 Introduction to nuclear power reactors

Nuclear energy is a way of creating heat through the controlled release of energy from splitting the atoms (fission) of elements such as uranium and plutonium. Neutrons are also released during the process, which if captured by other fissile atoms can prompt further fission, creating a chain reaction. This chain reaction is controlled using neutron absorbers allowing for continuous fission. The energy released from continuous fission in the fuel is used to make steam, which is used to drive the turbine-generator to produce electricity (as in most large thermal power plants).

Nuclear power plants extract energy from the fission of atoms, they do not use oxygen to sustain combustion like conventional power plants, therefore they do not directly produce sulphur dioxide, nitrogen oxides, fine particles, mercury or other pollutants, that are produced in the combustion of fossil fuels and cause e.g. health impacts, ground-level ozone formation and acid rain. Nor does operation of a nuclear power plant produce carbon dioxide or other greenhouse gases causing global warming of the climate.

Nothing is burned or exploded in a nuclear power plant, the fuel (many tonnes of uranium) is carefully contained in fuel rods, which are arranged into fuel assemblies for insertion and removal from the reactor. Some reactor types replace the fuel at discrete intervals, other designs utilise continuous refuelling. The fuel core can be thought of as a reservoir from which energy can be extracted through the fission chain process.

There are several components common to most types of reactors used or available for commercial operation today:

Fuel: Usually pellets of uranium dioxide (UO_2) arranged in gas tight metal tubes to form fuel rods. Uranium can be used in its natural form or can be enriched to increase the content of fissile material. Other possible fuel types include MOX (Mixed Oxide) fuel and thorium based fuels.

Natural uranium contains 0.7 % of the only naturally occurring fissile isotope uranium 235. Without the use of an efficient moderator such as heavy water, a chain reaction cannot be sustained. Reactors which employ a less efficient moderator, such as light water, must increase the amount of fissile material with in the fuel to compensate. PHWR reactors use heavy water as a moderator allowing the use of natural uranium as a fuel. Light water reactors employ uranium enriched by up to 5 % uranium 235.

MOX fuel, otherwise known as Mixed Oxide fuel is a mixture of uranium dioxide (UO_2) and plutonium dioxide (PuO_2). Typically about one percent of the used fuel discharge from a reactor is plutonium and about two thirds of this is fissile (containing plutonium 239 and plutonium 241). The plutonium along with depleted uranium can be reused by mixing to form MOX fuel. Assuming the plutonium composition comprises two thirds of the fissile isotopes, MOX fuel consisting of about 7-9 % plutonium mixed with depleted uranium is equivalent to uranium oxide fuel enriched to about 4.5 % uranium 235. A PHWR reactor can operate on 100 % MOX fuel. Most PWRs can run on a core loading of 30-50 %. Some advanced LWRs such as the EPR and AP1000 have been designed to accept complete fuel loadings of MOX fuel.

Thorium can also be used as a nuclear fuel through breeding to uranium 233. Thorium 232 will absorb slow neutrons to produce uranium 233, which is fissile and long-lived. The breeding cycle can be initiated using another fissile material such as uranium 235 or plutonium 239. All mined thorium is potentially useable. CANDU reactors are currently the only reactors able to employ thorium as a fuel.

The fuel rods are arranged into fuel assemblies (also called "bundles" in some designs) in the reactor core. The fuel core of a reactor may have up to 1100 fuel assemblies for BWRs, and typically between 150 and 260 for PWRs, held in place by end plates and supported by metal spacer grids to brace the rods and maintain proper distances between them (for cooling). The core of a PHWR may have up to 520 fuel channels each containing 12 fuel bundles. During operation of the reactor the concentration of useful (fissionable) atoms in the fuel decreases as those atoms are used to create heat energy. The products created by the fission reactions are retained within the fuel pellets and build up to affect the effective utilisation of the remaining fissionable fuel. Eventually a point is reached where it is necessary to replace some of the fuel, either "at power" or during a temporary reactor shutdown (typically a few weeks), depending on the reactor design. The amount of energy extracted from nuclear fuel is called its "burn up", which is expressed in terms of the energy produced per initial unit of Uranium fuel weight (commonly MW·d/MTU, GW·d/MTU).

Current LWR systems typically achieve average burn ups in the range of between 40 and 50 GW·d/MTU. New designs aim to achieve 50 to 60 GW·d/MTU. The CANDU burn ups are around 7 to 8 GW·d/MTU, while the ACR aims to achieve 20 GW·d/MTU. The lower the burn up the more spent fuel produced.

Discharged fuel contains the waste products of fission many of which are radioactive and through a process of radioactive decay continue to generate heat for significant periods after shutdown and removal. Spent fuel is initially stored at the reactor site in water in special cooling ponds – large concrete vaults lined with stainless steel in a dedicated building. These pools of water provide both cooling (of the fuel rods) and shielding to protect people and the environment from residual ionising radiation.

<u>Control Rods</u>: These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the reactor core to control the rate of the fission chain reaction, or halt it. As a means of increasing safety (in case some event prevents successful operation of the control rods) reactor designs include secondary shutdown systems which involve adding other neutron absorbers usually into the primary cooling system.

<u>Coolant/ Moderator</u>: A liquid or gas circulating through the reactor core is used to transfer heat from the fuel rods to the turbine-generator, either in a direct cycle (such as Boiling Water Reactor, see below) or indirect cycle via a steam generator (other water reactors and current commercially operating gas reactors). The circulating coolant also provides a moderating function to improve the efficiency of the neutron fission process in current commercial power reactors. The moderator slows neutrons, increasing their chance of capture by a fissile atom. In some reactors a separate moderator is used (e.g. CANDU (heavy water in a tank surrounding the primary coolant/ fuel channels) or RBMK (graphite)). The choice of moderator influences the design of the reactor core and fuel cycle, particularly the amount of enhancement (enrichment) of fissile Uranium during the fuel rod production process, the amount of energy that can be extracted from each fuel rod and the size (power density) of the reactor core.

<u>Pressure Vessel or Pressure Tubes</u>: Usually a robust steel vessel over 20 cm thick containing the reactor core and moderator/ coolant, but it may also be a series of tubes

holding the fuel and conveying coolant through the moderator (e.g. as CANDU and RBMK).

Primary Circuit: The system which conveys coolant containing heat from the reactor core either directly to the turbine-generator or to a steam generator. After transfer of energy the cooled coolant is returned to the reactor core in a closed cycle. Attached to the primary circuit are a number of auxiliary "primary systems" which are used for chemistry (corrosion) and volume control of the coolant.

Some reactor designs are based on prevention of phase change (boiling) in the primary circuit and incorporate a pressurizer to suppress boiling. This allows the circulating water and steam at the turbine to hold more energy per unit volume which increases the efficiency of energy transfer in nuclear power plants containing a secondary circuit. These designs are those that have an intermediate steam generator and separate secondary (steam-feedwater) circuit supplying steam to the turbine-generator.

Turbine-Generator: The turbine (one or several) converts the steam into rotational energy which drives an electricity generator. Roughly a third of the generated heat energy can be converted to electrical energy. The excess heat is usually released into the environment. From the turbine, the steam is led to the condensers, where it condenses back into water for reheating in the reactor core. The water used for cooling in the condensers warms up by a few degrees Celsius and is either discharged to a body of water or led to cooling towers. Water which circulates inside the reactor primary circuit may contain small quantities of fission and activation products, but this water is not mixed with the condenser cooling water at any time.

Containment: The enclosure or structure around the reactor core, and some parts of the primary circuit and safety systems (extent depending on reactor design), which is designed to protect it from outside intrusion and by providing a major barrier, to protect those outside from the effects of radiation or the release of radioactivity. The containment structure is typically a metre-thick pre-stressed concrete structure lined with steel, in modern designs designed to withstand the impact of a crashing aircraft, for example. Some designs incorporate two containment shells.

It can be seen that there are a number of features that affect the design of nuclear power plant reactor systems, and each design incorporates benefits and compromises. It is noted here that the evolution of reactor designs has produced increasing levels of safety and for the present worldwide commercial development is focused on water-based reactors. These are described below in general terms; detail of candidate designs under consideration for the new NPP in Lithuania is provided in Section 5.2.

5.1.2 Plant type options for Lithuania

Most of the nuclear reactors in the world are so-called light water reactors (LWR). LWR uses regular water to transfer the heat away from the reactor core. It also acts as a moderator. There are two types of LWR designs: 1) the pressurized water reactor (PWR) and 2) the boiling water reactor (BWR). In addition, PHWR (pressurized heavy water reactors) reactor types are included in the options being considered.

Pressurized Water Reactor (PWR)

This is the most common type of commercial reactor and was originally developed in the USA for submarine propulsion. Roughly 60 % of the world's commercial reactors are PWRs.

The uranium dioxide fuel is enriched to about 4–5 % and contained in zirconium alloy tubes, typically 3.5–4 m in length. Pressurised water acts as both moderator and coolant and heats water in a secondary circuit via a steam generator to produce steam which is used to drive the turbine(s) (Figure 5.1-1).

The PWR operates under a high pressure; this acts to increase the boiling point of the coolant, enabling more efficient heat transfer. The coolant in the primary circuit is kept at operating pressures of typically 120–155 bar. A pressurised water reactor plant has two separate circulation systems; the primary system, which circulates the water pumped through the core to the steam generator (heat exchanger), which transfers heat to the secondary circuit and produces saturated steam. Pressurised water in the primary circuit is heated up to 300–330 ºC. The water in the secondary circuit is heated up to 260–290 ºC and kept at a lower pressure (45–78 bar), this allows the water to boil and generate the steam required to drive the turbine. A PWR's thermal efficiency is 32–37 %.

The reactor is encased in a concrete containment which is designed to withstand internal pressures resulting from a sudden rupture of the pressurised primary water circuit, and external impacts such as aircraft crash.

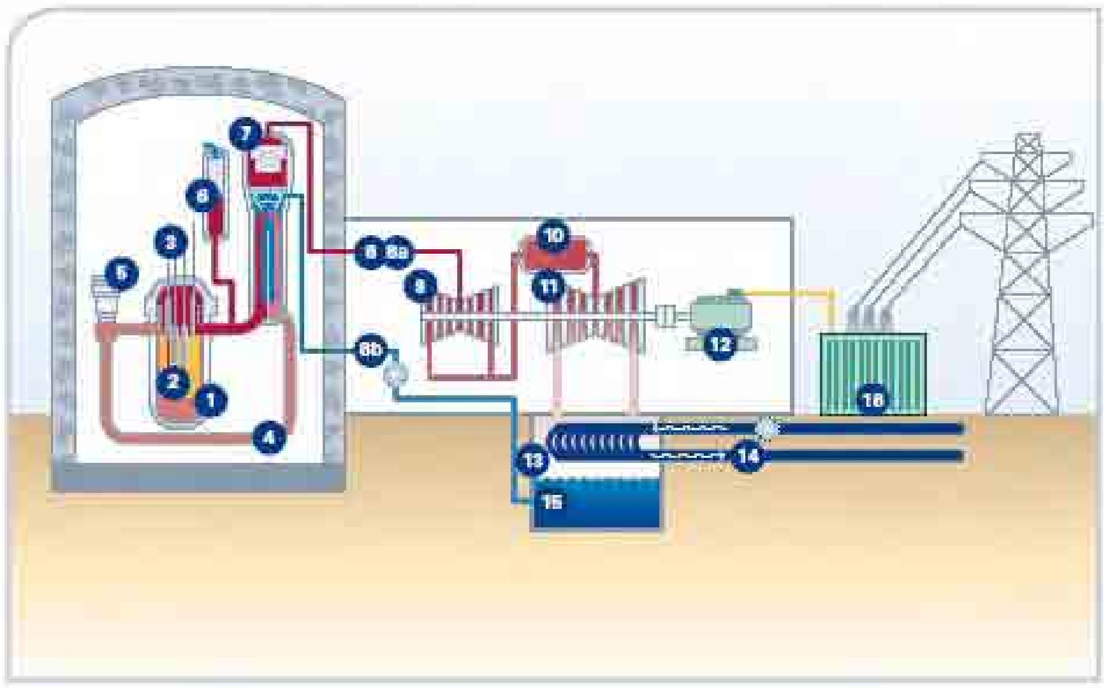


Figure 5.1-1. Key Features of a Pressurised Water Reactor: (1) Reactor, (2) Core, (3) Control rods, (4) Primary circuit (water circuit), (5) Main reactor coolant pump, (6) Pressurizer, (7) Steam generator, (8) Secondary circuit (steam-water), (8a) Steam for the turbine, (8b) Water for the steam generators, (9) High pressure turbine, (10) Reheater, (11) Low pressure turbine, (12) Generator, (13) Condenser, (14) Cooling circuit, (15) Condensation water, (16) Transformer.

Boiling Water Reactor (BWR)

A BWR is effectively a PWR without the steam generator (Figure 5.1-2). Water is circulated through the core again acting as both moderator and coolant, inside a pressure vessel. This heats the water to a temperature of approximately 300 °C, which makes it boil and generate steam at a pressure of approximately 70 bar. About 10 % of the water is converted to steam and passed to steam turbines. After condensing it returns to the pressure vessel to complete the circuit. The fuel is similar to that of a PWR, but the power density (energy per unit volume of core) is about half, with lower temperatures and pressures. This means that for equivalent heat output BWR pressure vessels are larger than for PWR, but the absence of steam generators and lower system pressures means the reactor containment may be smaller.

The cost advantage of a single circuit (i.e. not having steam generators) is offset by potential radioactive contamination throughout the steam plant in the event of fuel failures. With lower pressures (70 bar) and temperatures the thermal efficiency of BWR is slightly less than a PWR.

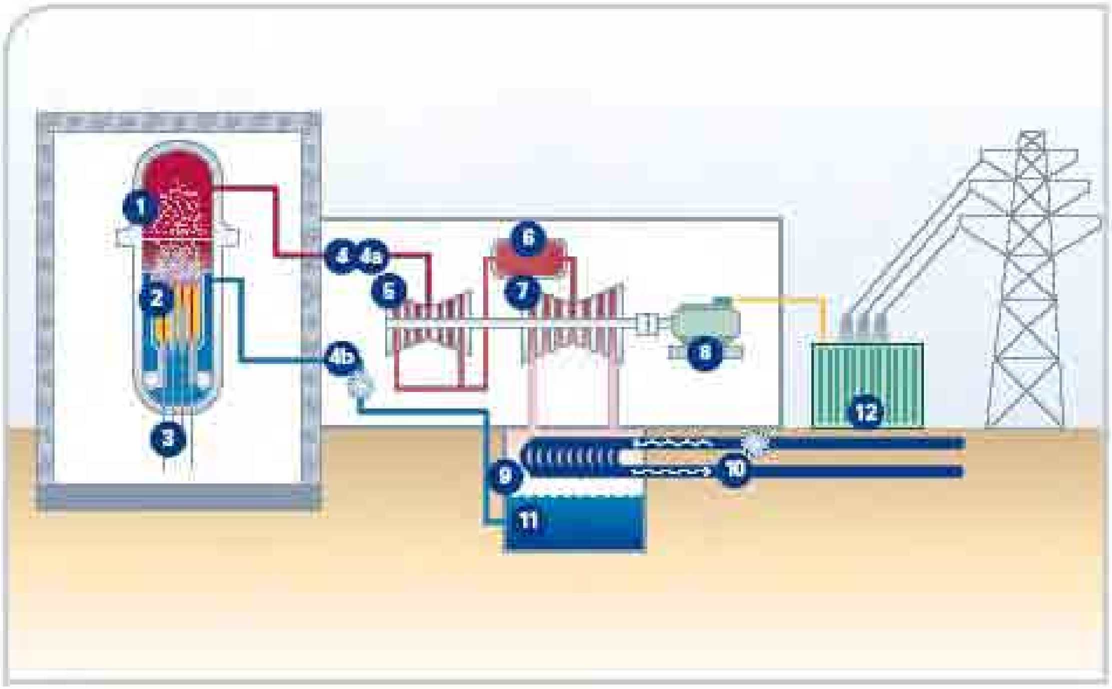


Figure 5.1-2. Key Features of a Boiling Water Reactor: (1) Reactor, (2) Core, (3) Control rods, (4) Primary circuit, (4a) Steam for the turbine, (4b) Water for the reactor, (5) High pressure turbine, (6) Reheater, (7) Low pressure turbine, (8) Generator, (9) Condenser, (10) Cooling water circuit, (11) Condensation water, (12) Transformer.

Pressurized heavy water reactors (PHWR)

The first commercial PHWR CANDU (CANadian Deuterium Uranium) reactor was designed by Canadian company AECL. CANDU uses deuterium oxide (a special form of water) as both coolant and moderator. This permits the use of natural or low enriched uranium dioxide fuel contained in zircaloy tubes. Extraction of heat from the core in the CANDU reactor design is similar to that of the PWR employing the use of a pressurised primary circuit and a secondary circuit, but instead of a large pressure vessel, the uranium fuel is placed in hundreds of horizontal pressure tubes (called channels). These are cooled by heavy water, which removes heat from the core in the same way as the PWR. The pressure tubes sit in a large vessel, or calandria, containing a separate heavy water moderator at low pressure (Figure 5.1-3).

The average power density is about one-tenth that of a PWR, which means that for a comparable output the reactor and its containment are correspondingly larger in size.

PHWR fuel differs from PWR/ BWR fuel, being much shorter in length, with several fuel bundles (typically 12, each 50 cm long) placed end to end in a fuel channel. The fuel tube/ bundle arrangement means that CANDU reactors can be refuelled at power, which increases potential availability. The primary circuit typically operates at 120 bar and 285 °C, leading to a thermal efficiency of about 30 %.

The Advanced CANDU Reactor, ACR, see section 5.2, is a hybrid of PWR and PHWR technology, using slightly enriched fuel with a light water primary coolant to increase the power density and extend the burn up of the fuel, resulting in reduction in size and spent fuel arisings compared to its natural uranium equivalent.

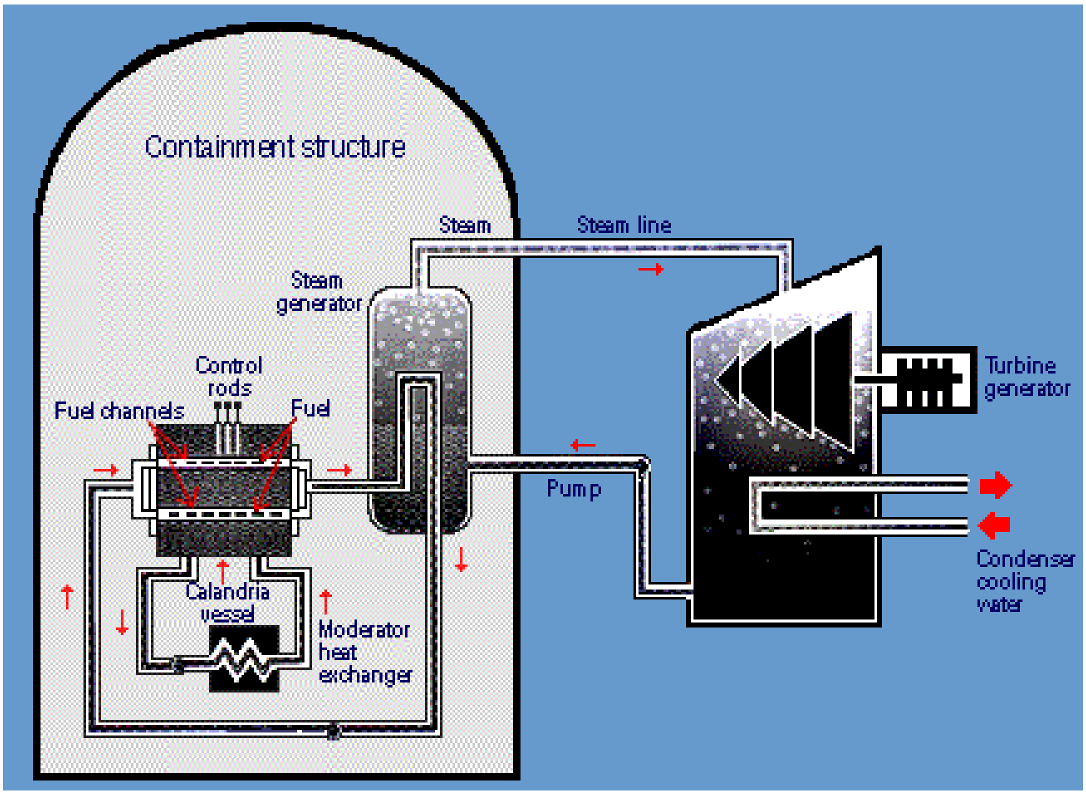


Figure 5.1-3. Key Features of a pressurized heavy water reactor (ACR type).

5.1.3 Technical requirements of new nuclear power plant

Detailed specification of technical requirements for the new nuclear power plant will be developed under a separate work package as the project proceeds, hence cannot be stated in this EIAR. Plant output considerations are described elsewhere in this report; this section identifies a principal source of technical requirements for the new nuclear power project.

The major European electricity producers have worked on a common requirement document (European Utilities Requirements document, EUR) for future LWR plants since 1992 to get specifications acceptable to potential owners and operators, the public and the safety authorities. Production of a common requirements document would enable designers to develop standard LWR designs that could be acceptable across Europe and the utilities could open consultations with vendors on a common basis. Communication with the public and regulatory authorities should also be improved. The EUR promoters are a group of organizations that represent the major Western Europe electricity producers. It is likely that the EUR will form a major input to the specification for a new NPP in Lithuania.

The major objectives of the EUR document have been to develop requirements addressed to the LWR plant designers and vendors. It is a tool for promoting the harmonization of the most important plant features that historically were often country specific. More recently the harmonised requirements of the European Safety Regulators have been prepared in the frame of WENRA (Western European Nuclear Regulator Association). The main items considered in this convergence process are the safety approaches, targets, criteria and assessment methods, the standardised environmental design conditions and design methods, the performance targets, the design features of the main systems and equipment, and – at a lower level – the equipment specifications and standards. The EUR addresses not only safety requirements, but many industrial and operational factors.

The EUR document is structured in 4 volumes (see www.europeanutilityrequirements.org). The whole document includes about forty chapters and some 4000 individual requirements covering a variety of plant design, performance and safety related topics:

- Volume 1: Main policies and top tier requirements; It is guidance on the safety policies and it defines the major design objectives that are implemented in the EUR document;
- Volume 2: Generic nuclear island detailed requirements; it contains all the generic requirements and preferences of the EUR utilities for the nuclear islands. It deals with matters applicable for all designs such as size, performance, safety approach and objectives, grid requirements, fuel cycle, component technology and functional requirements for systems;
- Volume 3: Design specific nuclear island requirements; It contains a subset specific to each nuclear power plant design of interest to the participating utilities. Part 1 of this subset includes a plant description, Part 2 presents the results of the conformance assessment of the design versus the generic EUR requirements of Volume 2 and Part 3 contains the specific requirements, if any, that have been placed by EUR for the particular design;
- Volume 4: Power generation plant requirements; It contains the generic detailed requirements for the Balance of Plant.

The EUR promoters are producing evaluations of selected LWR designs, the results of which are included in Vol. 3 of the EUR document. Presently seven subsets dedicated to GE's ABWR, Westinghouse BWR90, EPP and AP1000, Areva's EPR and SWR1000, and Russian WWER AES92 projects have been published and a further subset dedicated to the Mitsubishi APWR is undergoing preliminary compliance assessment. The requirements are also being employed for the design of the ESBWR. It is expected that further designs may be sponsored by EUR promoters for assessment in the future. Formal assessment of a design for compliance with the EUR can take 18 months.

It is to be noted that the EUR document is a reference user's document for LWR plants to be built in Europe, but it is not a document for licensing the plants. Also the EUR has no regulatory status. The plant designs will always need to duly comply with the national licensing regulations and laws. Moreover, in case of any selected technology, including also PHWR reactors, applicable regulations, standards, IAEA safety guides and best available practice etc. will be applied.

It is necessary to register to EUR to obtain access to the main requirements sections of the EUR. However, the following key safety requirements (based on open literature, e.g. *Scherrer Institute paper and INTERNATIONAL ATOMIC ENERGY AGENCY, "Status of advanced light water cooled reactor designs 1996", IAEA Report, IAEA-TECDOC-968, September 1997*) are highlighted as the key safety related aspects of EUR compliant reactor systems:

- Application of "As low as reasonably achievable (ALARA)" principle;
- Forgiving design characterized by simplicity and passive safety features where appropriate;
- Safety classification based on: Design Basis Condition (DBC) and Design Extension Conditions (DEC);
- Redundancy and independence of safety systems performing DBC and some DEC functions to ensure prevention of common cause failure;
- For DBC's reaching a safe shutdown state within 24 hours from the accident initiation and in any case within 72 hours. For DEC a safe shutdown state should be reached within one week as a goal and before 30 days in any case; The confinement of fission products and protection against external events in normal operation, DBC and DEC's. The containment should not experience early failure under DEC conditions;
- The containment design has to exclude hydrogen detonation;
- If in-vessel coolability can not be demonstrated, then ex-vessel coolability and non-criticality features must be provided;
- The leakage rate from the containment should not exceed 0.5-1.0 V%/day for a pre-stressed concrete shell without a liner, 0.1-0.5 V%/day with a liner or for a metal shell;
- On-line monitoring of containment leak-tightness during operation;
- The containment should not remain at elevated pressure after the accident. The pressure should be reduced at least to 50 % of its peak value in the worst DBC;
- Requirement for a secondary containment, for example by a partial solution of enclosing all penetrations;
- Secondary bypass leakage should not exceed 10 % of the primary containment leakage;
- Next generation of NPP's will be safer by increasing design robustness, better operation and maintenance (preventive means) rather than through protective actions;
- If possible, public evacuation planning should not be necessary (for a site boundary of 800 m);
- For accident prevention – simplification of the safety systems, elimination of common mode failures by physical separation and diverse back-up systems, less sensitivity to human errors by designing components with larger inventories of water, optimized man-machine interface by digital instrumentation and control systems, use of probabilistic risk assessment to limit the residual risk due to total loss of safety grade systems;
- Target frequency of:
    - core damage accidents (No action necessary beyond 800 m from the damaged plant, very limited economic impact out of the plant), with containment intact: $< 10^{-5}$/ reactor year;
    - criteria for limited impact (No immediate Emergency Protection Action beyond 800 m from the reactor; no delayed action at any time beyond about 3

km from the reactor; no long term action at any distance beyond 800 m from the reactor; limited economic impact out of the plant): <10^{-6}/ reactor year;

- Sequences potentially involving either the early failure of the Primary Containment or very large releases: < 10^{-7}/ reactor year.

5.2 REACTOR DESIGN OPTIONS

A general description of the design and key safety features for those reactor designs being considered for the new NPP in Lithuania is given in this section. The descriptions are not comprehensive and demonstrate only some selected features for each plant type. A technical/safety comparison of the plant types should not be made on the basis of this information it has been included only to give the reader a more general idea of the plant design. Reactor designs being considered are presented in Table 5.2–1.

Table 5.2–1. Reactor designs being considered for the new NPP.

Output, MW_e	Reactor Type	Model	Supplier	Generation	Website[1]
600	PWR	AP-600	Westinghouse-Toshiba	III+	www.ap600.westinghousenuclear.com
700	PHWR	EC-6	Atomic Energy of Canada Limited	III	www.aecl.ca/Reactors/CANDU6.htm
1006	PWR	V-392	Atomstroyexport	III	www.gidropress.podolsk.ru/english/razrab_e.html
1085	PHWR	ACR-1000	Atomic Energy of Canada Limited	III+	www.aecl.ca/Reactors/ACR-1000.htm
1100	PWR	AP-1000	Westinghouse-Toshiba	III+	www.ap1000.westinghousenuclear.com
1254	BWR	SWR-1000	Areva NP	III+	www.areva-np.com
1300	BWR	ABWR	GE-Hitachi	III	www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors.htm
1500	PWR	V-448	Atomstroyexport	III	www.gidropress.podolsk.ru/english/razrab_e.html
1535	BWR	ESBWR	GE-Hitachi	III+	www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors.htm
1660	PWR	EPR	Areva NP	III+	www.areva-np.com
1700	PWR	APWR	Mitsubishi Heavy Industries	III	www.mhi.co.jp/atom/hq/atome_e/apwr/index.html

1 – Information on reactor systems has been taken from published sources with particular emphasis given to the web sites of the Vendor organisations as listed in this table. Additional information is taken from publicly available documents provided by reactor suppliers in support of regulatory review or assessment, for example the web sites of the US NRC and UK HSE.

The sections that follow provide further information on these reactors, highlighting key features of the design and comments regarding the status of the design in terms of interest by electricity utilities and licensing. This information is at time of writing subject to continuous change. This information is provided to indicate the possible type of nuclear power plant that may be constructed in Lithuania, not to indicate or imply any selection at this time. Selection of the preferred plant design and licensing acceptance will be undertaken at a later stage in the NPP development program.

For ease of presentation, information below is by vendor, rather than ordered by power output.

Areva NP

European Pressurised Reactor (EPR)

The EPR is an evolutionary PWR manufactured by Areva/Framatome ANP. This generation III+ reactor is designed to generate up to 1600 MW of electricity. The EPR has been developed from the Framatome N4 units and the Siemens/KWU Konvoi plants, currently operational in France and Germany. Several utilities companies have participated in the design, including EDF, E.ON, RWE, and EnBW. The reactor design follows an evolutionary approach, however safety relies either of active safety features or passive and inherent safety provision, such as the Generation III+ designs.

The EPR is based on 4-loop PWR technology with a single large turbine-generator and incorporates 4 train safety systems to deal with internal or external events that may affect the reactor safety. The reactor containment building has two walls, the first, an inner pre-stressed concrete housing with a metallic liner, encapsulated by the second wall comprised of a reinforced concrete shell. The containment building has a specially-designed corium spreading area. In the event of core meltdown, this is where any molten core escaping from the reactor vessel would be collected, retained and cooled. The diesel building contains four emergency diesel generators and their support systems to supply electricity to the safeguard trains in the event of a power blackout.

The EPR design is shown in Figure 5.2-1.

Figure 5.2-1. Schematic of the principal buildings of an EPR (*www.areva-np.com*).

The reactor can be fuelled with either up to 5 % enriched Uranium or up to 100 % MOX fuel. The EPR is designed to achieve the highest unit power to date, mainly due to economies of scale. Other factors such as shortened construction times, high thermal efficiency due to raised steam pressures in the secondary circuit, and improved reliability/availability resulting from on-line maintenance for components of the reactor building, help achieve this.

Construction time of the NPP is approximately 45 months. The first EPR is currently under construction in Olkiluoto, Finland. Operation was originally scheduled for 2009, but TVO have recently announced that construction problems have resulted in a delay of around 18 months; operation is now expected in 2010/2011. Construction of an EPR reactor at Flammanville, France has commenced and orders have been placed for China and the USA.

Siede Wasser Reaktor (SWR-1000)

The SWR 1000 is a generation III+ advanced boiling water reactor, originally designed by Siemens (now part of Areva), with a design output of 1254 MW of electricity. The design is based on German boiling water reactor technologies, modified to include integral recirculating pumps for the primary circuit, simplifying the design. Passive safety systems have been introduced into the design, alongside proven active safety systems. The design has also been simplified; features include the adoption of a single-train feedwater heating system, and the removal of the feedwater tank and the re-heaters.

A schematic of the reactor part of the SWR 1000 is given in Figure 5.2-2.

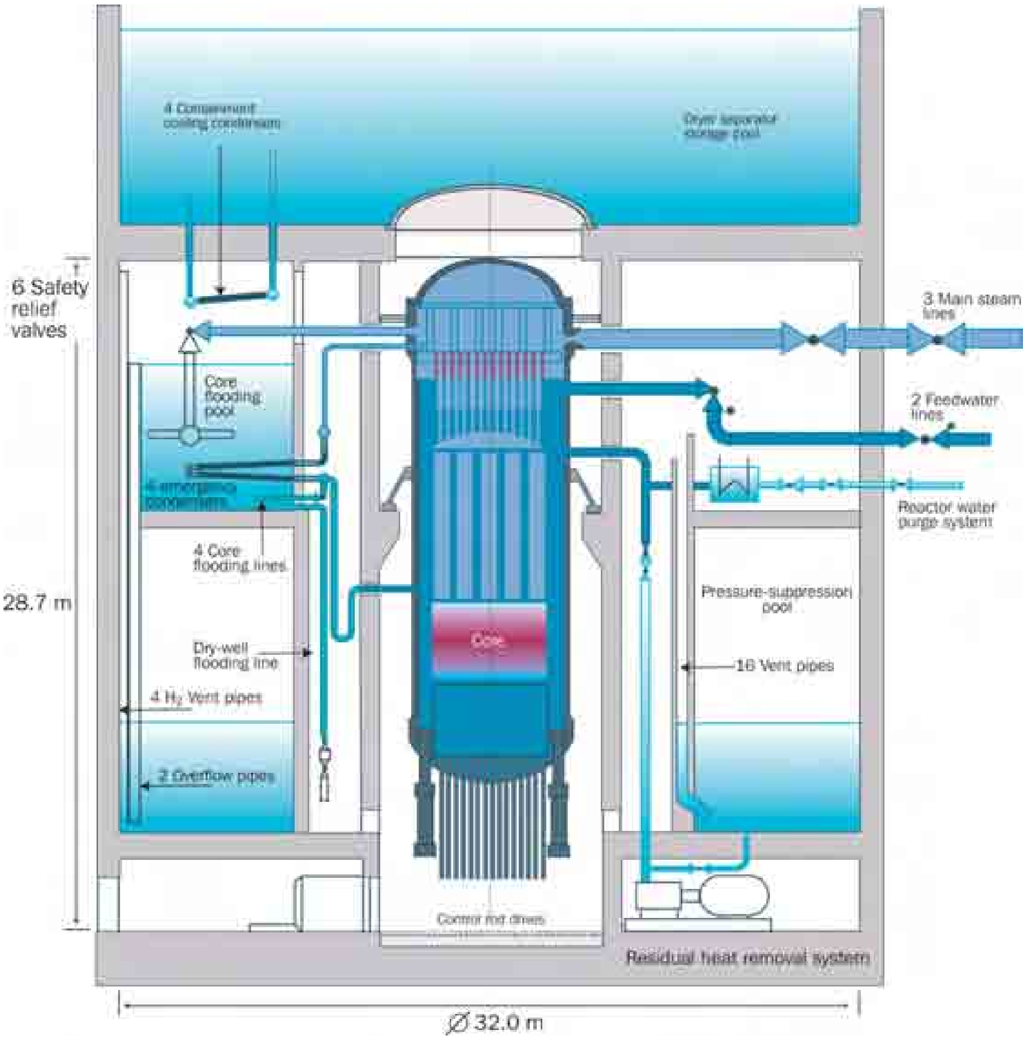


Figure 5.2-2. A Schematic of the Reactor part of the SWR 1000 (*www.areva-np.com*).

Safety design features include: an increased water inventory in the reactor pressure vessel which completely covers the core with water during de-pressurisation, lengthening the time available to provide additional makeup water before fuel overheating, addition of core flooding pools inside the containment provide a large storage capacity for the accommodating system, and a passive heat removal system via the containment cooling condensers.

A construction schedule of less than 48 months is stated.

The SWR-1000 was certified as EUR compliant in Feb 2002. The SWR-1000 is one of three nuclear power plants being considered by Fennovoima for its planned nuclear power plant in Finland.

General Electric-Hitachi

Advanced Boiling Water Reactor (ABWR)

The ABWR is a large, forced circulation, direct-cycle BWR reactor. It is of Generation III reactor design, capable of generating 1300 MW of electricity. The design is based on GE's long history of BWR development. The ABWR is one of the designs produced under the USA's joint EPRI/DOE Advanced Light Water Reactor Development Program, initiated in 1987.

In the direct-cycle BWR system the cooling water is allowed to boil as it passes upward through the reactor core, producing steam. A schematic of the reactor core is shown in Figure 5.2-3. The steam is dried and passed directly to power the turbines, after which the steam is condensed and returned to the core.

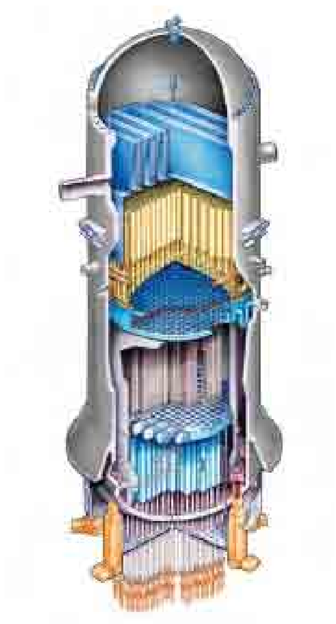


Figure 5.2-3. Schematic of the reactor core of the ABWR (*www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors.htm*).

Enhancements to the design improve safety, reliability and economic performance. These include the replacement of the external recirculation pumps with internal ones, to allow the elimination of large diameter nozzles below the top of the core. This, along with a reduced number of forgings, has greatly reduced the need for both welds and primary circuit piping. This simplifies construction and reduces occupational radiation exposure by reducing the need for in-service inspection. The reactor building encapsulating the core allows for secondary containment. Both the reactor pressure vessel and the reactor building are integrated to improve the overall seismic response. A fully digital instrumental and control system provides enhanced reliability and accuracy.

Lower operator doses are achieved through the use of improved fuel materials and coolant chemistry control and a reduction in the use of cobalt bearing alloys.

The plant layout is very similar to the EBWR reactors, as shown in Figure 5.2-4. The design allows for modular construction, within 39 months. The ABWR is certified as EUR compliant (2000) and has been issued with NRC Design Certification in the USA (March 2008).

The ABWR design is licensed in three countries, the United States, Japan and Taiwan. The first ABWR to be built was Unit 6 at Kashiwazaki in Japan, and has been operational since 1996. Four further ABWR units are operational in Japan, with more under construction and planned.

Economic Simplified Boiling Water Reactor (ESBWR)

The ESBWR is a generation III+ plant, manufactured by General Electric-Hitachi Nuclear Energy (GEH) and has evolved from the direct-cycle BWR system. In designing the ESBWR, GE have simplified the design and reduced costs, allowing for faster construction, lower operating costs and enhanced safety. This has been achieved by employing a natural circulation system in the core and passive safety systems. The ESBWR has been designed to produce 1550 MW of electricity.

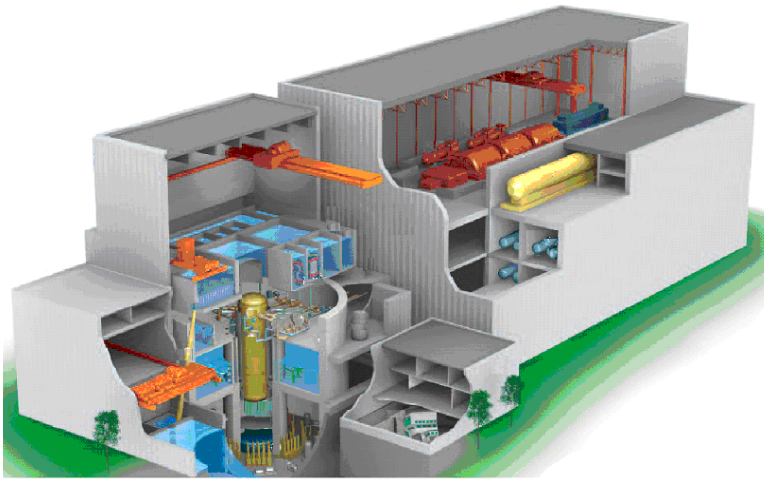


Figure 5.2-4. A schematic of the ESBWR plant design (*ESBWR fact-sheet, 2007*).

The ESBWR incorporates an advanced natural circulation system for the pressure vessel and passive safety systems, which rely on natural forces such as gravity, evaporation and condensation for plant operations, instead of the large numbers of active pumps and valves used by existing reactors. A total of 11 systems have been removed from previous designs, resulting in a 25 % fewer valves, pumps and motors.

Heat produced in the core is converted directly to steam, circulation of water occurs naturally in the core, as the water is heated it rises and forms steam, which is then diverted to the turbine. This natural circulation eliminates the need to use recirculation pumps, simplifying the design. Although present in all BWR's, natural circulation is enhanced in the ESBWR by extending the chimney region above the core, improving the steam separator, and by providing a clearer flow path between the down-comer and the lower plenum.

The ESBWR reactor core, illustrating the natural circulation system, is presented in Figure 5.2-5.

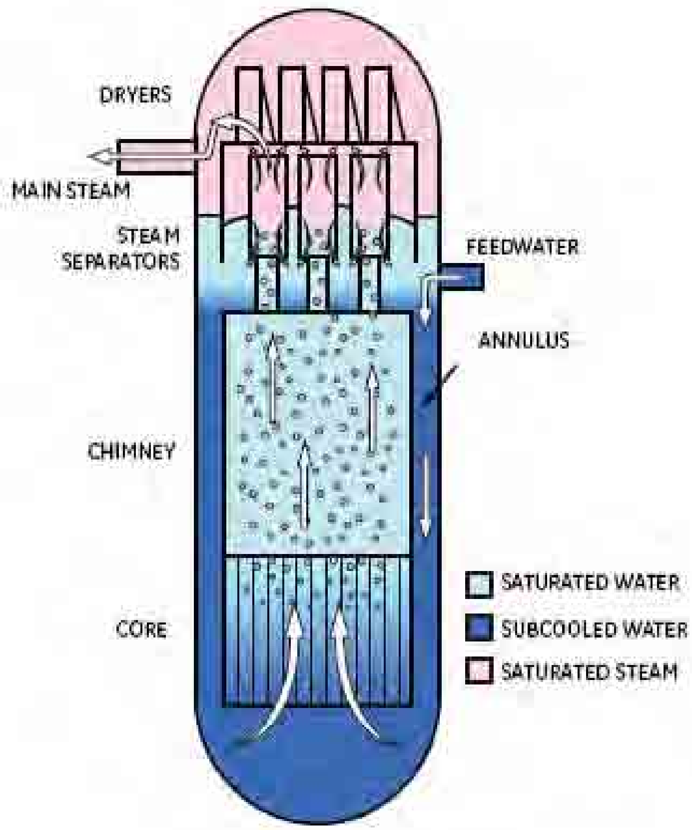


Figure 5.2-5. The ESBWR reactor core, illustrating the natural circulation system (*ESBWR fact-sheet, 2007*).

Passive safety features have been favoured in the ESBWR design. Active components such as pumps, motorized valves, and other powered devices are replaced by systems whose operation is independent of external power. The Emergency Core Cooling System consists of passive safety features, as follows (*General Electric Fact Sheet*):

- An Automatic Depressurisation System (ADS), which employs safety relief valves on the main steam lines that discharge steam to the suppression pool and drywell in the event of a system over pressure.
- A Gravity Driven Cooling System (GDCS), which uses gravity to provide makeup water following a depressurization vent.

Other passive features include:

- The Isolation Condenser System (ICS). The ICS removes decay heat from the reactor following transient events involving reactor scram, including station blackout. The ICS consists of four independent high pressure loops, each containing a heat exchanger that condenses steam on the tube side, this system uses natural circulation to remove decay heat.
- The Passive Containment Cooling System (PCCS). The PCCS removes heat from inside containment following a LOCA. The system consists of four safety-related low-pressure loops. Each loop has a heat exchanger open to the containment, a condensate drain line and a vent discharge line submerged in the suppression pool. The four heat exchangers, similar in design to the isolation condensers, are located in cooling pools external to the containment.

Entergy Corp, Dominion and the utility consortium NuStart Energy Development, have each selected the ESBWR for several potential nuclear projects in the United States.

The ESBWR is currently undergoing NRC design certification in the USA, certification is expected in 2010. It is favoured for early US construction and could be operational in 2014. Construction time is quoted as approximately 36 months.

Westinghouse-Toshiba

AP600

The AP600 is an advanced pressurised water reactor, designed to produce 600 MW of electricity, and is considered to be a Generation III design. A two-loop layout is used which reduces the physical footprint of the NPP. The AP600 was designed as part of the Advanced Light Water Reactor (ALWR) Program in the USA in the 1990's.

The AP600 was designed to incorporate a number of passive systems, thereby simplifying the design and reducing the numbers of active components (i.e. pumps, motorised valves, chillers) present in traditional PWR technologies. These have the effect of reducing operational and construction costs. The AP600 led the introduction of "passive" safety technology to water-cooled reactor systems.

Passive safety systems are used for emergency core cooling and containment cooling. Three separate water sources are employed for emergency cooling. Short-term high-pressure coolant is injected from core make-up tanks and accumulators. Two tanks filled with borated water are designed to function at any reactor coolant system pressure using only gravity, and the temperature and height difference from the reactor coolant system leg as the motivating force. Long-term cooling is supplied by an in-containment refuelling water storage tank. Water from this tank flows under gravity into the reactor cavity; heat is removed by convection and boiling. Water vapour rises and condenses on the surface of the steel containment vessel, the condensate then drains back into the refuelling water storage tank under its own gravity. Containment cooling is provided by the continuous, convective air-cooling of the steel containment vessel, which can be supplemented by the evaporation of water draining under gravity from the tank situated on top of the containment building.

Other key features of the design include employment of highly reliable "canned motor" pumps, mounted directly in the channel head of each steam generator. This pump design does not require shaft seals, which simplifies the auxiliary fluid systems, reduces maintenance, and eliminates possible accidents involving seal failures. The integration of the pump suction into the bottom of the steam generator channel head simplifies the steam generator and piping support systems.

The overall design of the power plant is shown in Figure 5.2-6.

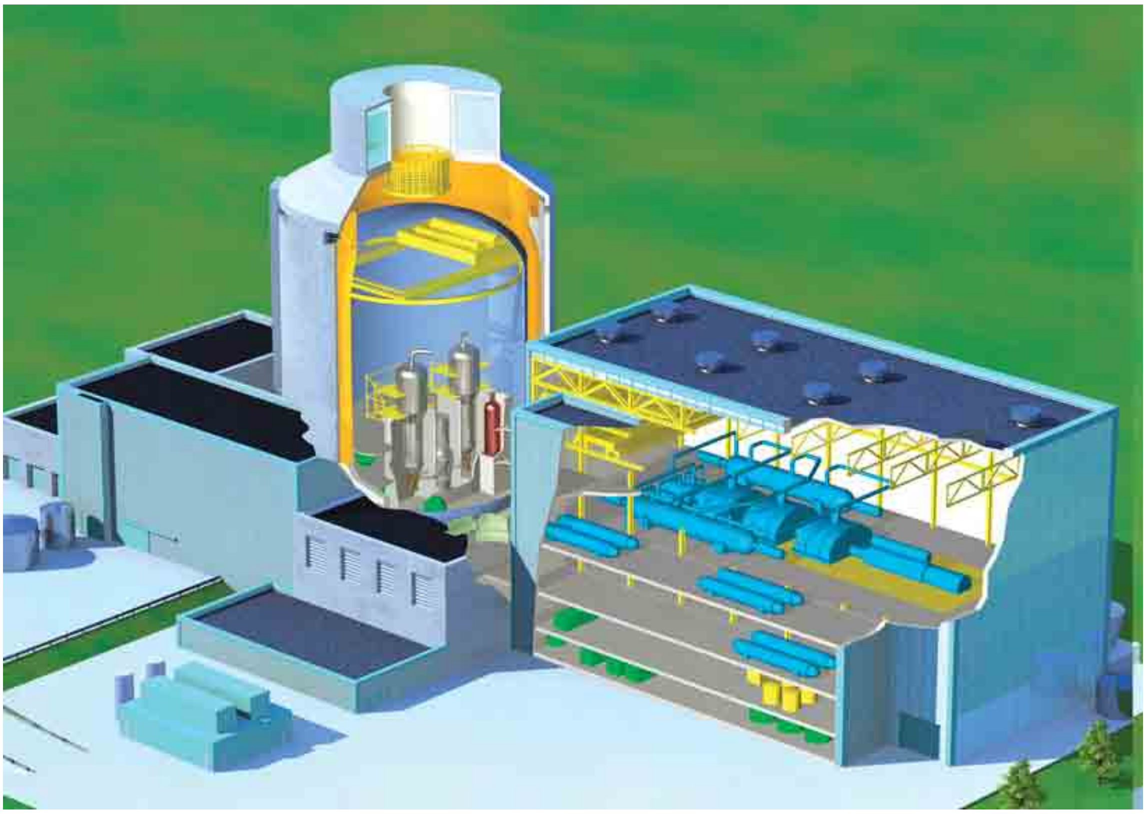


Figure 5.2-6. An illustration of the AP1000/AP600 nuclear power plant design (*AP1000 fact-sheet 2007*).

Final design approval from the U.S. Nuclear Regulatory Commission was received in 1998. The AP600 is also certified as EUR compliant (2000), however no orders have been placed to date.

AP1000

The AP1000 generation III+ design is derived from the AP600 plant design. The primary purpose of developing the AP1000 was to retain the AP600 design objectives, design details and licensing basis, while optimizing the power output, thereby reducing electricity generation costs. The AP1000 is designed to generate 1117 MW of electricity. The footprint of both the AP1000 and AP600 are the same, increased power output was achieved by increasing water flow through pipe size, and increasing the size of the canned motor, pressuriser, steam generator and reactor vessel.

The AP1000 has a reduced number of active components compared to a similarly sized conventional PWR plant. It is constructed in modules, which can be fabricated prior to transportation to the construction site. A construction schedule of 36 months is anticipated.

In May 2007 Westinghouse applied for UK generic design assessment (pre-licensing approval) based on the US Nuclear Regulatory Commission (NRC) design certification, and expressing its policy of global standardisation. The application was supported by utilities including E.ON. It has been selected for building in China and is under active consideration for building in Europe and USA.

Atomic Energy of Canada Limited

Enhanced CANDU 6

The Enhanced CANDU 6 is a Generation III plant, unique in its design; it is the only reactor to use deuterium oxide (heavy water) as a moderator. It is designed to produce up to 740 MW of electricity. A schematic of the reactor is shown in Figure 5.2-7. Using heavy water allows the reactor to achieve a high neutron economy (the efficiency with which a critical system uses neutrons), essential to the viability of a natural U fuel cycle (avoiding the need to produce and use enriched U).

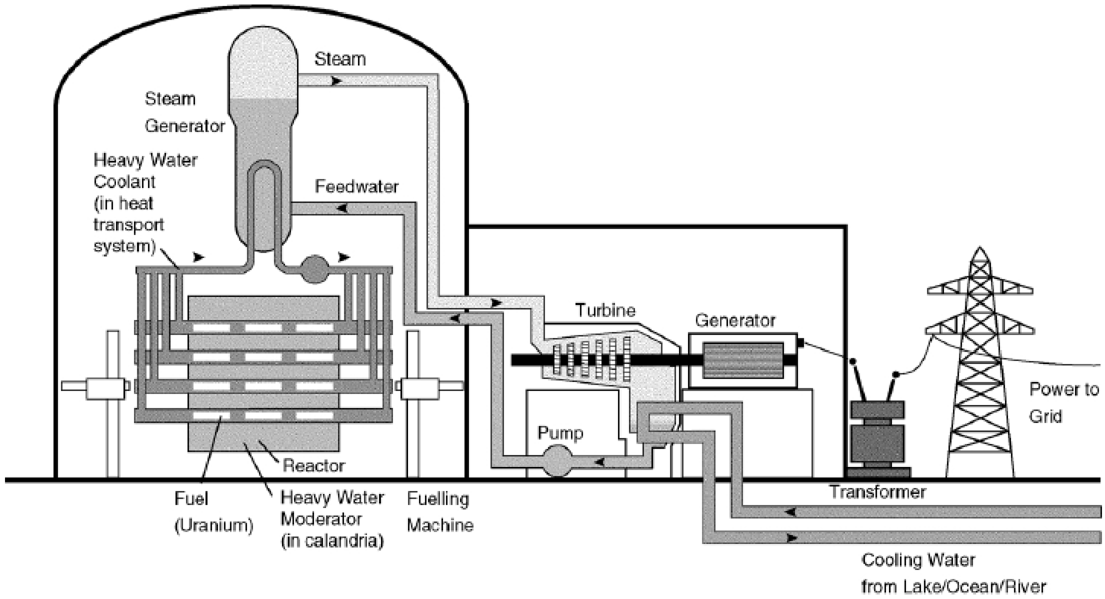


Figure 5.2-7. Schematic of the overall CANDU nuclear plant (*www.aecl.ca/reactors/*).

The high neutron economy also allows the potential for utilising different fuel types. The main fuel type for the CANDU 6 design is natural U, although a variety of different fuels such as MOX and TH/U233 can be used. CANDU reactors can also utilise spent PWR fuel.

The reactor is designed to be refuelled at full power, reducing the amount of time the plant is offline. The core is divided into 380 separate pressure tubes, each having a string of 12 natural U fuel bundles immersed in heavy water coolant. These tubes are positioned horizontally, reducing the complexity of the refuelling process. A fuelling machine visits each end of the core, one fuelling, while the other de-fuels. Fuel management provides the flux shaping, essential for increasing efficiency of the core and for long-term fuel management. Short term reactivity control is provided by controllable light-water compartments and absorber rods.

The primary coolant circuit of CANDU reactors is a two-loop design with a figure of eight configuration. This reduces the effect of a loss of coolant accident, caused, for example, by a pipe failure.

The Enhanced CANDU 6 incorporates passive safety features, including two independent shutdown systems. Emergency core cooling is provided by a passive emergency coolant injection system. Short-term high-pressure coolant is injected from core make-up tanks and accumulators. The long-term cooling system provides long-term recovery and recirculation of the coolant. The cool, low-pressure moderator also serves as a passive heat sink from the fuel channels in the event of severe accident.

Other safety features include a containment system, which provides a pressure-retaining envelope around the reactor core and primary circuit. This prevents the release of radioactive material to the environment. A spray system connected to the elevated reserve water tank will reduce reactor building pressures, if required, in the event of a severe accident. Finally, air coolers, located in various compartment of the reactor building provide heat removal and reduce pressures.

Following completion of Cernavoda unit 2 (October 2007), Romania is currently preparing for the completion of unit 3 and 4, commissioning is due in October 2014 and mid 2015 respectively.

Advanced CANDU Reactor (ACR-1000)

The Advanced CANDU Reactor 1000 (ACR-1000), is a development of the CANDU series of pressurised heavy water reactors (PHWR), developed by Atomic Energy of Canada Ltd (AECL). The ACR has been designed to produce 1085 MW of electricity.

The ACR is designed to retain fundamental features of the CANDU design, while achieving higher efficiency and lower capital costs. The ACR design still retains the use of heavy water as a moderator, however incorporates light water into the design as the coolant. Light water is circulated through the pressure tubes containing the fuel bundles and around the primary circuit. The adoption of the light water coolant reduces the heavy water inventory, and therefore capital costs. Fuel burnup is improved through the use of slightly enriched Uranium fuel by 1–2 %, this extends the fuel life to three times that of existing natural Uranium fuel.

The ACR is a two-loop design with a figure of eight configuration; the operational principles are similar to those described in Section 5.1 for a standard PWR. The main difference is that the light water coolant passes through pressure tubes instead of a pressure vessel. Heat is removed from the core using the same techniques as the PWR.

Safety systems are similar to those of the Enhanced CANDU-6.

Construction is in modular form, with a time span of 42 months. The footprint of the two-unit plant has been minimised with the adoption of common areas. The size of the power block for a 2 unit ACR-1000 station is 48000 m^2. The reactor is designed to allow on-power fuelling, resulting in longer operating cycles between maintenance outages (3 years).

The ACR is currently undergoing a pre-licensing review by the Canadian Nuclear Safety Commission and utility. The first ACR1000 is expected to be built in Canada, and could be producing electricity by 2014.

Mitsubishi Heavy Industries

Advanced Pressurised Water Reactor (APWR)

The APWR generation III+ design has been under development by Mitsubishi Heavy Industry (MHI) in collaboration with four Japanese utilities and Westinghouse, since the 1990's. It is a large four-loop PWR design based originally on Westinghouse technology, but incorporating several new design features which combine active and passive safety features. These include four independent safety Trains (both mechanical and electrical), an advanced accumulator system and elimination of low head safety injection system and containment isolation.

The APWR is in the process of being licensed in Japan, with the first two units (1538 MW_e generating capacity) to be constructed, at Japan Atomic Power Company's Tsuruga site (unit 3 and 4). Operation is expected by 2014.

Schematic of the US-APWR design is shown in Figure 5.2-8.

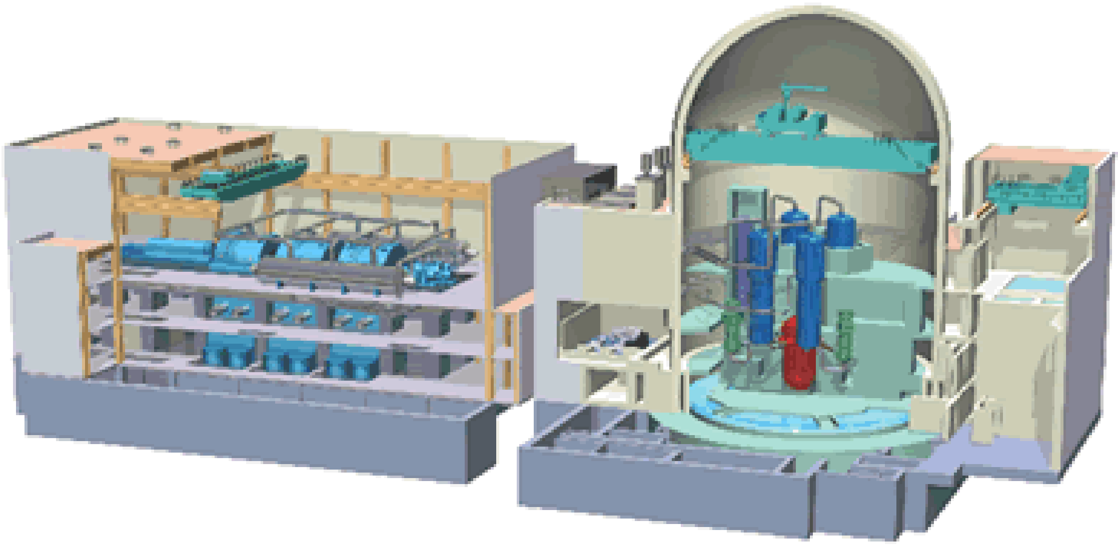


Figure 5.2-8. Schematic of the US-APWR design (*US-APWR fact sheet, 2007*).

MHI have also developed the US-PWR, an enhanced version of the APWR to be marketed in the USA and Europe, and is undergoing NRC Design Certification. This version offers several enhancements, including a 20 % reduction in plant building volume, a higher output of 1700 MW and a 24 month fuel cycle. The main components of the reactor system are enlarged in size corresponding to the large thermal output and improved plant efficiency.

<u>Atomstroyexport</u>

V-392 (or the advanced WWER-1000)

The earliest WWER's were developed by the USSR before 1970. The most common one of these designs, the WWER-440 Model V230, employs six primary coolant loops, each with a horizontal steam generator. The modified version of the WWER-440, Model V-213, was a product of the first uniform safety requirements drawn up by the Soviet designers. This model included added emergency core cooling and auxiliary feedwater systems as well as upgraded accident localisation systems. The larger, WWER-1000 design, developed after 1975 is a four-loop system housed in a containment type structure with spray type steam suppression system.

One such WWER-1000 system is the Temelin power station located in the Czech Republic, housing two 1000 MW reactors. Two turbines each power a 1000 MW alternator. The entire turbine set for the Temelin Nuclear Power Station was made by Skoda Pilsen.

The Russian design organisation OKB-Gidropress offers several variants of the WWER pressurised water reactor system. The V-392 has evolved from the WWER-1000, and generates 1000 MW of electricity using fuel of 4.3 % enrichment. Several enhancements in improvements have contributed to enhanced safety and improved economy, including incorporation in to the design an advanced steam generator, a reactor coolant pump with advanced design of seals, a passive heat removal system and a passive system of rapid Boron injection.

A schematic of the WWER-1000 nuclear power plant is shown in Figure 5.2-9.

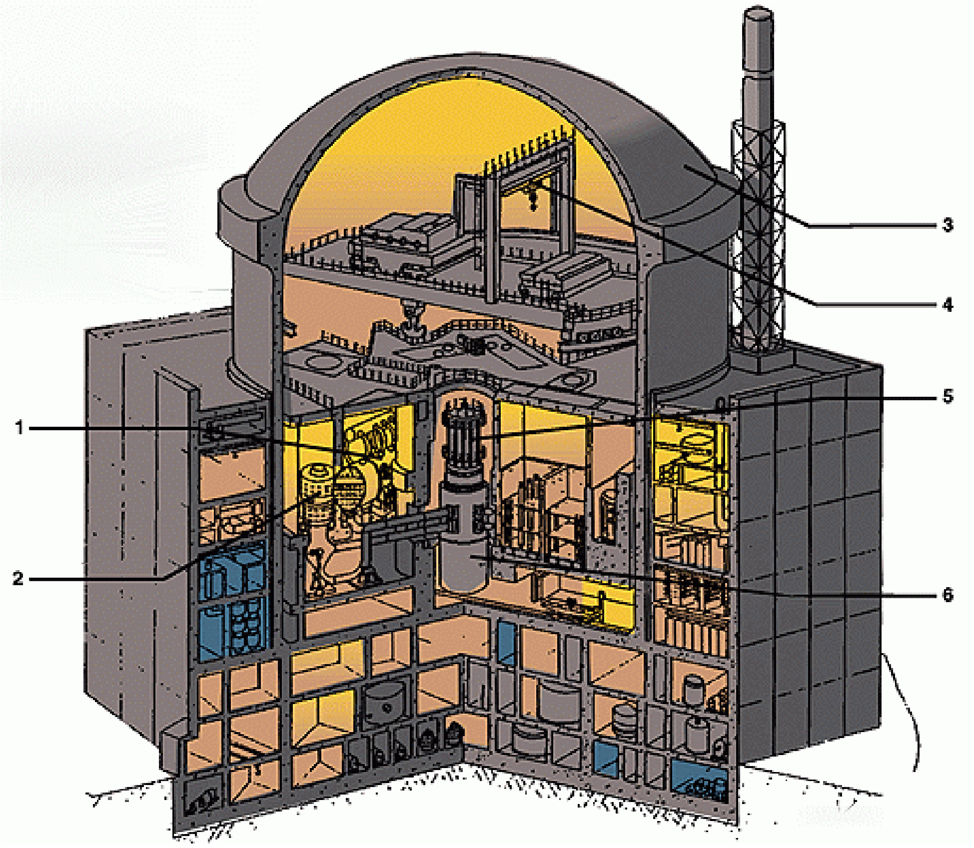


Figure 5.2-9. A schematic of the WWER-1000 nuclear power plant: (1) Horizontal steam generator, (2) reactor coolant pump, (3) containment building, (4) refuelling crane, (5) control rod assemblies and (6) reactor vessel (*International Nuclear Safety Centre Website*).

The V-392 units are planned for Novovoronezh and are being built in India. Construction time is 54 months.

V-448 (or the WWER-1500)

The V-448 is also a 4 loop pressurised water reactor with the capacity to generate 1500 MW of electricity. Enhanced features include a larger reactor vessel, decreased core power density compared with the WWER-1000, a longer fuelled zone and enhanced performance horizontal steam generators.

The design includes two protective shell containments with a ventilation gap between. The inner containment ensures leak tightness of the volume within the reactor unit and its major auxiliary components. The outer containment is capable of withstanding all natural or manmade impacts on the NPP, e.g. aircraft crash, explosion, tornado etc. The volume between the shells contains two independent ventilation systems providing an additional degree of containment, one active and one passive.

A passive emergency shutdown system is employed by gravity insertion of control rods or fast injection of boron into the coolant. A passive heat removal system is also incorporated into the design in the event of an accident without a large loss of primary coolant. Heat is removed through the steam generators, transferring heat to surrounding air through specific heat exchangers located outside of the protective casing. In the event of core melt, it is technically possible to contain the molten core within the reactor vessel, if for some reason the molten core isn't contained it will be collected in a special container under the reactor vessel.

This model is being developed, and two units are planned as replacement plants for Leningrad and Kursk. The first units are expected to be commissioned in 2012-2013.

Table 5.2–2. Comparison table of reactor designs being considered for the new NPP.

Reactor design	EPR	SWR-1000	ESBWR	ACR-1000	ABWR	AP600	AP1000	EC-6	V-392	V-448	APWR
Supplier	Areva NP	Areva NP	GE-Hitachi	AECL	GE-Hitachi	Westinghouse-Toshiba	Westinghouse-Toshiba	AECL	Atomstroy-export	Atomstroy-export	Mitsubishi
Reactor Type	PWR	BWR	BWR	PHWR	BWR	PWR	PWR	PHWR	PWR	PWR	PWR
Thermal Power, MW	4300	3370	4500	3187	3926	1933	3400	1982	3000	4350	4350
Electrical Power, MW	1600	1254	1535	1085	1350	600	1100	700	1006	1500	1700
Efficiency	~37%	~37%	~34%	~34%	~34%	~32%	~32%	~35%	~34%	~35%	~39%
Reactor Design											
Moderator	Light Water	Light Water	Light Water	Heavy Water	Light Water	Light Water	Light Water	Heavy Water	Light Water	Light Water	Light Water
Coolant	Light Water	Light Water	Light Water	Light Water	Light Water	Light Water	Light Water	Heavy Water	Light Water	Light Water	Light Water
Coolant System Pressure, bar	155	75	71.7	111	71.7	155	155	117.5	157	157	155
Reactor Outlet Coolant Temp ºC	328	292	282	319	300	316	321	310	321	330	310
Major Components											
Vessel/ Tube	Vessel	Vessel	Vessel	Horizontal Tube	Vessel	Vessel	Vessel	Horizontal Tube	Vessel	Vessel	Vessel
Steam Generator	4	No	No	4	No	2	2	2	4	4	4
Pressuriser	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Core Coolant System	Four-loop system	Forced circulation	Natural circulation	Two-loop system	Forced circulation	Two-loop system	Two-loop system	Two-loop system	Four-loop system	Four-loop system	Four-loop system
Fuel											
Enrichment (maximum)	5.00%	3.54%	4.20%	1.90%	4.20%	4.95%	4.95%	0%	3.3-4.4%	4.50%	5.00%
Number of Fuel Assemblies	241	664	1132	6240	872	145	157	4560	163	241	257
Refuelling	Shutdown	Shutdown	Shutdown	At power	Shutdown	Shutdown	Shutdown	At power	Shutdown	Shutdown	Shutdown

Reactor design	EPR	SWR-1000	ESBWR	ACR-1000	ABWR	AP600	AP1000	EC-6	V-392	V-448	APWR
Fuel Cycle length	12, 18 or 24	12 or 24	12 or 24	Continuous	18 to 24	18	18	Continuous	12 or 24	12 or 24	24
Safety Compliance											
UK GDA	In progress						In progress				
EUR	Yes	Yes	In progress		Yes	Yes	Yes	Yes		Yes	In progress
US NRC	Pre-certification	Pre-certification	In progress	Pre-certification	Yes	Yes	Yes	Pre-certification			In progress
Operator Actions	72 hours	72 hours	72 hours	24 hours	72 hours	72 hours	72 hours	24 hours	24 hours	24 hours	72 hours
Emergency Systems											
Shutdown											
Control Rods	√	√	√	√	√	√	√	√	√	√	√
Boron Injection	√	√	√		√	√	√		√	√	√
Gadolinium Injection				√				√			
Core Cooling											
Passive	√	√	√	√	√	√	√		√	√	√
Active	√	√	√	√	√	√	√	√	√	√	√
Containment											
PCCV + liner	√	√	√		√	√	√		√	√	√
RC structure	√	√	√	√+liner	√	√	√	√+liner	√	√	√
Safety Analysis											
Core Damage Frequency[1]	1.33×10^{-6} (Int + Ext)	1.1×10^{-7} (Int)	6.2×10^{-8}	3.4×10^{-7} (Int)	1.6×10^{-7} (Int)	-	5.1×10^{-7} (Int + Ext)	4.6×10^{-6}	5×10^{-8}	-	$<1 \times 10^{-7}$
Large Release Frequency[1]	9.28×10^{-8}	-	$<1 \times 10^{-8}$	-	$<1 \times 10^{-9}$	-	$<5.9 \times 10^{-8}$	-	-	-	-

All designs are operational over a 60 year lifetime, with up to 92 % availability.

[1] The Core Damage Frequency and Large Release Frequency will have been calculated different for each reactor, based on the different methodology and assumptions. The value quoted has been obtained directly from the vendor. All designs meet IAEA design targets of 1×10^{-5} for Core Damage Frequency and 1×10^{-6} for Large Release Frequency. Units are 1/reactor years.

Table 5.2–3. CDF and LRF references.

Model	CDF Reference	LRF Reference
EPR	EPR – Rapport Preliminaire de Surete de Flamanville 3. Version Publique, Electricité de France, 2006	EPR – Rapport Preliminaire de Surete de Flamanville 3. Version Publique, Electricité de France, 2006
SWR-1000	Swr 1000: AREVA's Advanced, Medium-Sized Boiling Water Reactor With Passive Safety Features. Werner Brettschuh, AREVA NP GmbH.	-
ESBWR	ESBWR Design Control; Document, Tier 2, 2007.	US NRC requirement is for LRF to be <0.1 CDF
ACR-1000	AECL web site, ACR-1000, Enhanced Safety	-
ABWR	Beard, J. A. ABWR Safety – PRA, Containment Response & Severe Accidents; GE Energy/Nuclear Presentation, 2007.	Beard, J. A. ABWR Safety – PRA, Containment Response & Severe Accidents; GE Energy/Nuclear Presentation, 2007.
AP-600	-	-
AP-1000	UK API000 Design Acceptance Application, Wesinghouse, 2007	UK API000 Design Acceptance Application, Wesinghouse, 2007
EC-6	AECL, Candu Safety – #20, Probabilistic Safety Analysis, 2001	-
V-392	IAEA – International Atomic Energy Agency (2004): Status of advanced light water reactor designs 2004; IAEA-TECDOC-1391, May 2004.	-
V-448	-	-
APWR	IAEA – International Atomic Energy Agency (2004): Status of advanced light water reactor designs 2004; IAEA-TECDOC-1391, May 2004.	-

5.3 FUNDAMENTALS OF NUCLEAR SAFETY MANAGEMENT

5.3.1 Introduction

Nuclear energy has been produced in Lithuania for the last 25 years at the Ignalina NPP: Unit 1 started commercial operation in 1983 and was finally shutdown 31st December 2004; Unit 2 is expected to cease operation in 2009. During these years, valuable experience has been gained in the operation and regulation of a nuclear power plant; this complements the high-quality knowledge that has been acquired through systematic domestic research and international cooperation in the field of nuclear safety.

The use of nuclear energy is associated with a concern for the possibility of different incidents and accidents and the environmental impacts of potential radioactive releases in such situations. Of particular concern is a repetition of the consequences of an environmental release such as occurred during the Chernobyl accident. Lessons have been learnt from such events, and legislation and procedures are in place to ensure such an event does not occur again. There are no plans to build any more RBMK-1000 reactors, or reactors similar in design (such as the RBMK-1500 currently employed at Ignalina) with international pressure to close those that remain. For preventing accidents and limiting their consequences, high safety culture and special safety principles and regulations are required in the design and operation of nuclear power plants. The use of nuclear power in Lithuania requires a license and it is regulated by law.

The following laws relate to the application of nuclear energy in Lithuania (*Ministry of Economy, www.ukmin.lt/en/energy/nuclear/relevant/ index.htm*):

- Law on the Nuclear Power Plant, 28 June 2007, No X-1231 (As amended 1 February 2008 No X-1446);
- Law on Nuclear Energy, 14 November 1996, No I-1613 (As amended 2 July 2002, No IX-1021);
- Law on Radiation Protection, 12 January 1999, VIII-1019;
- Law on the Management of Radioactive waste, May 20 1999, No VIII-2506 (As amended 26 October 2004).
- Law on Civil Protection, 12 December 1998, No. VIII-971 (State Journal, 1998, No. 115-3230).

These acts implement Lithuania's obligations as a signatory of the following IAEA Conventions:

- Convention on Nuclear Safety;
- Joint Convention on the Safety of Spent Nuclear Fuel Management and the safety of Radioactive Waste Management;
- Vienna Convention on Civil Liability for Nuclear Damage;
- Convention on Early Notification of a Nuclear Accident;
- Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency;
- Convention on the Physical Protection of Nuclear Material.

Also Lithuania has signed the triangular agreement between EU non-nuclear countries, IAEA and European Atomic Energy Community on application of safeguards and its additional protocol which came in force on 1st of January 2008.

Lithuania became a member of the International Atomic Energy Agency (IAEA) in 1993. The IAEA exists to pursue "safe, secure and peaceful uses of nuclear sciences and technology". After joining the European Union in 2004, Lithuania became am member of European Atomic Energy Community. One of the main EURATOM objectives – to ensure the establishment of the basic installations necessary for the development of nuclear energy, contribute to the increase of living standards in the Community and cooperation with other countries.

The new nuclear power plant in Lithuania will meet the requirements of Lithuanian laws and other legal acts and IAEA safety standards as well. Licenses (related to nuclear safety) are issued by VATESI after coordination with Ministry of Environment, Radiation protection centre and the local municipality.

5.3.2 Nuclear safety

<u>IAEA Safety Principles</u>

The IAEA's Fundamental Safety Principles for nuclear safety are given in the publication "Fundamental Safety Principles: Safety Fundamentals. IAEA Safety Standards Series, No. SF-1, Vienna: International Atomic Energy Agency, 2006". These principles and other IAEA publications will be used to guide the selection, justification and approval of the nuclear power plant project. The following text is based upon the IAEA publication:

The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation.

This fundamental safety objective of protecting people – individually and collectively – and the environment has to be achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. To ensure that facilities are operated and activities conducted so as to achieve the highest standards of safety that can reasonably be achieved, measures have to be taken:

- To control the radiation exposure of people and the release of radioactive material to the environment;
- To restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;
- To mitigate the consequences of such events if they were to occur.

The fundamental safety objective applies for all facilities and activities and for all stages over the lifetime of a facility or radiation source, including planning, siting, design, manufacturing, construction, commissioning and operation, as well as decommissioning and closure. This includes the associated transport of radioactive material and management of radioactive waste.

Ten safety principles have been formulated, on the basis of which safety requirements are developed and safety measures are to be implemented in order to achieve the fundamental safety objective. The safety principles form a set that is applicable in its entirety.

Principle 1: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.

Thus the licensee (power plant operating organisation or organisation which is planned to operate the plant) is responsible for:

- Establishing and maintaining the necessary competences;
- Providing adequate training and information;
- Establishing procedures and arrangements to maintain safety under all conditions;
- Verifying appropriate design and the adequate quality of facilities and activities and of their associated equipment;
- Ensuring the safe control of all radioactive material that is used, produced, stored or transported;
- Ensuring the safe control of all radioactive waste that is generated.

Principle 2: An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.

Section 5.3.3 describes the governmental framework and organisations involved in the regulation and support of nuclear power plant safety in Lithuania. The relevant Laws are identified together with descriptions of the relevant regulatory bodies and other State departments involved in administration of the safety of nuclear power plants in Lithuania.

Principle 3: Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.

During the licensing process of the new NPP activities, the Authority responsible for nuclear safety regulation, will examine the conformance of applied management system to regulations, its efficiency, how safety is considered in all chains of management, personnel competence, the ability of operating organisation to be consistent and responsible in improving the safety and activities

Principle 4: Facilities and activities that give rise to radiation risks must yield an overall benefit.

This is in part addressed by this Environmental Impact Assessment Report, and will also be required to be shown in subsequent licensing and permit applications for the project. The Law on Nuclear Power Plant (*X-1231*, *X-1446*) already establishes that the development of the plant is in the national interest of Lithuania.

Principle 5: Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Principle 6: Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Principle 7: People and the environment, present and future, must be protected against radiation risks.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Principle 8: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.

The most harmful consequences arising from facilities and activities have come from the loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or other source of radiation. Consequently, to ensure that the likelihood of an accident having harmful consequences is extremely low, measures have to be taken:

- To prevent the occurrence of failures or abnormal conditions (including breaches of security) that could lead to such a loss of control;
- To prevent the escalation of any such failures or abnormal conditions that do occur;
- To prevent the loss of, or the loss of control over, a radioactive source or other source of radiation.

The primary means of preventing and mitigating the consequences of accidents is "defence in depth". Defence in depth is implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment. If one level of protection or barrier were to fail, the subsequent level or barrier would be available. When properly implemented, defence in depth ensures that no single technical, human or organizational failure could lead to harmful effects, and that the combinations of failures that could give rise to significant harmful effects are of very low probability. The independent effectiveness of the different levels of defence is a necessary element of defence in depth.

At the highest level Defence in depth is provided by an appropriate combination of:

- An effective management system with a strong management commitment to safety and a strong safety culture.

- Adequate site selection and the incorporation of good design and engineering features providing safety margins, diversity and redundancy, mainly by the use of:
  - Design, technology and materials of high quality and reliability;
  - Control, limiting and protection systems and surveillance features;
  - An appropriate combination of inherent and engineered safety features.
- Comprehensive operational procedures and practices as well as accident management procedures.

Accident management procedures must be developed in advance to provide the means for regaining control over a nuclear reactor core, nuclear chain reaction or other source of radiation in the event of a loss of control and for mitigating any harmful consequences.

Principle 9: Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.

The primary goals of preparedness and response for a nuclear or radiation emergency are:

- To ensure that arrangements are in place for an effective response at the scene and, as appropriate, at the local, regional, national and international levels, to a nuclear or radiation emergency;
- To ensure that, for reasonably foreseeable incidents, radiation risks would be minor;
- For any incidents that do occur, to take practical measures to mitigate any consequences for human life and health and the environment.
- To ensure that emergency preparedness and response actions to nuclear and radiation accidents are in accordance to preparedness and management structure of extreme situations defined in the Law on Civil Protection.

Principle 10: Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

The safety analysis report(s) submitted in support of licence and permit applications will provide the required justification.

Safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation. Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.

<u>Defence in Depth</u>

It is clear above that nuclear safety is ensured through the application of the “defence in depth” approach. This concept concerns the protection of both the public and workers and is fundamental to the safety of nuclear installations. Its premise is that all safety activities, whether organizational, behavioural or equipment related, are subject to layers of overlapping provisions, so that if a failure should occur it would be compensated for or corrected without causing harm to individuals or the public at large. This idea of multiple levels of protection is the central feature of defence in depth (*International Nuclear Safety Advisory Group, 1996*).

Defence in depth is implemented through the design and operation to provide a graded protection against a wide variety of transients, incidents and accidents, including equipment failures and human errors within the plant and events initiated outside the plant.

The historical development has led to a general structure of five successive levels of defence, shown in Table 5.3–1.

Table 5.3–1. Levels of defence in depth (*International Nuclear Safety Advisory Group, 1996*).

Levels of defence in depth	Objective	Essential meaning
Level 1	Prevention of abnormal operation and failures.	Inherent safety principles, conservative design and high quality in construction and operation.
Level 2	Control of abnormal operations and detection of failures.	Control, limiting and protection systems and other surveillance.
Level 3	Control of accidents within the design basis.	Engineered safety features and accident procedures.
Level 4	Control of severe plant conditions, including prevention and mitigation of the consequence of severe accidents.	Complementary measures and accident management.
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials.	Off-site emergency response.

High quality, competent staff and responsible operation

In the design, construction and operation of a nuclear power plant, safety is ensured by high-quality operation and safety culture. Safety culture refers to the personal dedication and accountability of all individuals engaged in any activities which have a bearing on the safety of a nuclear power plant. High-quality construction and operation guarantee an undisturbed operation of a power plant. In addition to consistent electricity production, high safety-levels are also reached. The high-level of safety is ensured by the continuous quality control of the work, internal inspections, requirements guiding the operation, and inspections by the authorities.

Approval by the regulatory authorities is required for positions of responsibility within the nuclear power plant; such positions include the manager of the nuclear power plant, and any deputies, the person in charge of nuclear materials and emergency preparedness arrangements, and the operators of the nuclear power units. Training of new staff will also begin as early as in the construction stage as possible. During operation, all the staff, especially operators, will be trained on a regular basis. This training will involve the use of simulators where different scenarios can be practised and exercised. The operators must demonstrate their competence in regular exams.

Structures, systems and equipment of the nuclear power plant are classified according to their safety significance, and via derived technical specifications provide operational restrictions and functional requirements to satisfy the design intent of the plant. The classification is also used for focusing inspection, quality assurance and independent control by authorities on areas important in terms of continued safety.

Provision for incidents and accidents

A nuclear power plant must be designed in accordance with nuclear energy legislation and regulatory guides on nuclear safety in order to ensure the safety of its operation. According to the VATESI normative documents (*VD-B-001-0-97 and VD-T-001-0-97)*, fundamental safety functions are as follows:

- Management of reactivity;
- Fuel cooling;

- Localization of radioactive waste, control of operational releases and limitation of accident releases.

Fulfilment of these requirements ensures that the risk of a large-scale nuclear accident is very, very small. Safety functions are implemented both with parallel safety systems (redundancy) and with different operational principles (diversity). Parallel safety systems are segregated from each other so that, e.g. fire or other events cannot harm all parallel systems (common cause failure). Redundancy also provides protection against single failures of components in one of the parallel systems (trains). Diversity of systems providing a safety function provides protection against common mode failures, e.g. the use of both electrical and steam driven emergency feedwater pumps.

In the event of the failure of a safety system, defence in depth reduces the risk that a single failure of a critical system can lead to an accident. It denotes the practice of having multiple, redundant, independent safety systems. An example of this is two independent safety systems (the insertion of control rods and the addition of Boron (or another neutron poison) into the core) to inhibit fission in the core during the event of loss of control of the nuclear chain reaction. Diversity in the reactivity shutdown systems ensures that a specific safety requirement can still reliably be fulfilled i.e. if one system fails another system is in place to provide the same safety function (in this example shutdown of the reactor). Each safety system is adequate to control the reaction independently are each designed for high reliability of operation employing the principles of redundancy and segregation.

In normal operation fuel cooling is maintained by the continued flow of coolant through the core. In the event of pump failure, there exists enough redundancy in the system to maintain the flow of coolant. In the event of a loss of coolant accident (for example a sudden large failure of a primary coolant pipe), the Emergency Core Cooling (ECC) system is activated. This comprises multiple systems, which flood the core with coolant. Taking a PWR as an example the first system provides short-term coolant make-up to the reactor core through a high-pressure injection of water from accumulator and makeup tanks. The second system provides a long-term cooling system once the first system is finished; this second system may also have a normal operational purpose, to cool the reactor during maintenance. A second example considers events where there is a loss of main feedwater from the condenser to the steam generator. In this case an Emergency Feed Water (EFW) system is provided to remove the excess decay heat, drawing feedwater either from the condenser or reserve water feed tanks in case the condenser train is not available. This enables the reactor to be cooled down via the primary circuit and steam generator, with heat (steam) rejected to atmosphere or water source as available.

Prevention of radioactive releases

The uncontrolled release of radioactive material into the environment is physically prevented using a succession of isolating barriers. Each physical barrier has been designed to withstand the threats posed to them in potential accidents or incidents, and if the previous/inner barrier has broke down. The system of barriers includes:

- the ceramic fuel pellets;
- the fuel element cladding;
- the tight steel reactor system;
- the tight inner containment;
- the strong outer containment.

In a severe accident the most important barrier preventing the spread of radioactive waste into the environment is the double containment. This consists of the actual pressure proof, gastight inner containment made from either special steel, concrete or a combination of both. The outer containment is usually made of reinforced concrete. The outer containment surrounds the inner containment so that any gas leaking from the inner containment can be collected and filtered to minimise gaseous releases. The outer containment also acts as a radiation shield, ensuring radiation levels remain low outside, even if containment has been breached inside of the outer containment. The most important function of the outer containment is to protect the reactor from external hazards. It is expected that all new nuclear power plants will demonstrate a full capability to withstand the effect of airplane crash and other terrorist threats to the integrity of the reactor plant structures. New nuclear power plants are also designed for a high degree of tolerance to natural external hazards, including meteorological and seismic hazards. These are not expected to represent a significant threat to the new power plant, by virtue of design and careful siting.

Containment within new power plants is designed to withstand worst case scenarios; these severe accidents include core melt and during them the majority of the released fission products, gaseous radionuclides and aerosols remain contained inside the containment, so that health risks to the workforce and surrounding population are rather small.

Development of Reactor Safety Systems

Nuclear power plants have been developed over some 50+ years and are continuously being developed in many ways to improve their safety and operational reliability. These safety features have been developed during the evolution of reactor design.

This first and second generation of reactors (Generation I and II) utilised many “active” safety systems in their design to protect against plant malfunctions and failures of systems. These systems required electricity or hydraulic power for their operation and introduced significant complexity into the later power plant designs of the 1970’s (i.e. those operating commercially today).

Generation III rectors developed during the later 1980s and 1990s offer increased improvements in safety through the reduction of complexity by simplification of systems and incorporation of passive safety systems. Passive safety systems rely on the laws of nature, i.e. gravity, convection and evaporation, and do not require the input of either an operator or electronic system to be put in place like active systems. Passive systems are employed in many of the Generation III and above designs, and originate from the Westinghouse AP600 design developed in 1985. Westinghouse sought to dramatically simplify the safety systems operating in traditional PWR by the replacement of active components (valves, motors etc) with passive systems. The next generation of reactor, the Generation III+, are those which have recently been designed to incorporate advanced passive safety systems. These include the ACR, AP1000, ESBWR.

Generation IV reactors are currently being developed and are expected to come into commercial use in the next 20-30 years. The operational principles of these reactors are significantly different to the reactors in operation today and if materials performance issues can be resolved offer the potential for even safer reactors in the future. Such reactors still require significant development before a demonstration prototype can be considered.

Assessment of safety

While developing the design of a nuclear power plant the behaviour of the plant is studied experimentally and theoretically. Computer models are used extensively to simulate effects of plant deviations and accidents; this approach has been proven reliable. Different calculation methods are used for analysing the normal operation and a variety of various potential accidents within the power plant. Methods include: incident and accident analyses, strength analyses (to confirm plant integrity and margins usually via an approved design code, failure mode and impact analysis and probabilistic risk assessment. Assumptions and assessments made in the calculation models are verified such that when calculating uncertain factors, the worst choice in respect of the plant is always chosen, as even the worst cases must be managed safely. The results are used to determine the safety functions needed in accidents, and their safety margins are designed such that they function with high reliability.

After the completion of the nuclear power plant, the analyses are maintained, taking into account operational experience, experimental research results and the development of calculation methods. The documents are kept up to date and submitted to the Nuclear Safety Authority.

Safety of the operating nuclear power station is monitored regularly. Safety assessment is carried out either as a part of the renewal of the fixed-term operating licence of the power plant or at the latest ten years after the last assessment. As part of the periodic safety assessment, the licensee will assess the safety status of the power plant units, potential objects of development and the preservation of safety. This will include a summary of the revised safety analysis and conclusions from their results. Attention will be paid to requirements set in guidelines, control of ageing of the power plant units, obsolescence, implemented and potential plant improvements and safety culture and management.

5.3.3 Nuclear safety administration in Lithuania

Nuclear energy in Lithuania is regulated and administered by the following institutions: State Nuclear Power Safety Inspectorate (VATESI), the Ministry of the Environment, the Ministry of Health (via the Radiation Protection Centre), the Ministry of Social Security and Labour, the Ministry of Transport and Communications, the Ministry of National Defence, the Ministry of the Interior, the State Security Department, the Governmental Emergencies Commission and County Governors. It should be noted, that majority of legal acts which regulate activities of these institutions are related to the existing Ignalina NPP. During the implementation of the new NPP project, some of legal acts are already updated; some will be updated later taking into account the new NPP.

VATESI (established in 1991) is responsible for State regulation of the nuclear safety; safe management of radioactive waste in nuclear facilities; safe use of nuclear materials; physical protection of nuclear facilities and nuclear and radioactive materials used in nuclear facilities and the radiation protection.

In cases when ensuring nuclear safety involves other safety aspects significant for nuclear safety, e.g. fire protection, environmental protection, physical protection, emergency preparedness planning etc., responsibilities of regulation institutions are established by laws and other legal acts. VATESI cooperates with the other Lithuanian state regulation authorities and the respective responsibilities of certain authority are clearly defined and coverage is complete to ensure that no relevant aspects are overlooked.

VATESI is vested with executive authority by the Republic of Lithuania, and the Head of VATESI is appointed by the Prime Minister. VATESI reports to the Lithuanian Government and has direct recourse to the highest levels of Government, if required, to address safety issues.

VATESI performs its functions independently to the power plant developer, designer or operating organisation. VATESI controls and supervises nuclear safety of nuclear facilities and controls the accounting of nuclear materials in accordance with Lithuanian laws, its own regulations and other legal acts.

VATESI has offices in Vilnius and at the Ignalina NPP to ensure continuous monitoring of nuclear activities. VATESI also cooperates with various Lithuanian technical support organizations (Institute of Physics, Kaunas Technology University, Lithuanian Energy Institute, State Institute of Information Technology, Vilnius Gediminas Technical University and others) and with foreign and international institutions.

The main functions of VATESI are:

- Drafting and, with the authority of the government, approving safety standards and rules for the design, construction and operation of nuclear facilities, for storage of nuclear radioactive materials and for waste disposal;
- Ensuring adherence to the requirements set forth in licenses and safety rules and standards;
- Performs State accounting and supervision of nuclear materials;
- Issuing licenses for the design, construction, operation and decommissioning of nuclear facilities and of their systems as well as evaluating the safety of nuclear facilities;
- Annual report to the Lithuanian Government on the safety of nuclear installations;
- In the event of a nuclear or radiological accident, provide specialist interpretive advice and provides information to public and authorities;
- Provides information to state institutions, municipalities, natural and legal persons, public on nuclear safety and radiation protection.

Regarding the safe operation of nuclear plant, the role of VATESI includes inspection, surveillance, review, oversight, and in the case of some activities, the issuance of permits. VATESI has the right of access to all required documents and information.

On the basis that current (Ignalina NPP) regulatory practices are continued VATESI will maintain a group of inspectors at the plant site. Inspectors of the supervisory group visit the plant every day to perform their assigned functions and have access to operational documentation in both the main control room and other locations where work is carried out. VATESI can order the shutdown of a nuclear facility if it determines that regulations or standards of safety are being neglected.

The power plant operator is expected to submit the following reports to VATESI:

- annual report on nuclear power plant safety;
- reports on abnormal events during the whole plant lifetime including designing, construction, operation and decommissioning;
- reports on faults and defects in equipment of safety related systems (twice a year);
- monthly and annual reports on environmental impact (releases and discharges);
- annual and quarterly reports on radiation exposure of plant personnel, reports on cases of exceeding maximum permissible radiation levels and occupational diseases, etc.

VATESI requirements for Nuclear Power Plant safety are defined in the following documents:

- General Regulations for Nuclear Power Plant Safety, VD-B-001-0-97;
- Nuclear Safety Regulations for Reactor Facility of NPP, VD-T-001-0-97.

As part of work to examine the continued safety of operation of Ignalina NPP, these documents were confirmed against accepted Western practice as exemplified in the Basic Principles for NPPs:

- IAEA Safety Series No. 75 INSAG 3;
- Code on the Safety of Nuclear Power Plants: Design, IAEA Safety Series No. 50-C-D;
- Code on the Safety of Nuclear Power Plants: Operation, IAEA Safety Series No. 50-C-O;
- several of the relevant Safety Guides when more details were required.

IAEA documents are subject to periodic review and update. The relevant documents for the new nuclear power plant will be defined under a later stage of the project. Details of IAEA standards and guides can be accessed at www.iaea.org.

Any application to operate a new nuclear power plant will have to demonstrate compliance with Lithuanian laws and regulations and IAEA safety standards.

Current legislation in the nuclear field is based on the *Law on Nuclear Energy*. The law defines the principal objectives of state regulation of nuclear energy safety. The functions of control of safety of nuclear facilities are performed by the State Nuclear Safety Inspectorate of the Republic of Lithuania (VATESI).

The *Law on Environmental Protection* in conjunction with the *Law on Environmental Impact Assessmen*t stipulates that installation of any nuclear facility must be accompanied by an environmental impact assessment.

The Ministry of Environment controls releases of radionuclides and radiological monitoring in accordance with the provisions of *Lithuanian normative document on environmental protection LAND 42-2007* "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring". According to the *Republic of Lithuania Law on Nuclear Energy* the Ministry of Environment jointly with the Ministry of Health establishes radiation protection standards of the environment and monitors compliance with them; together with VATESI approves technical regulations for the design and construction of nuclear facilities; co-ordinates the projects for siting, reconstruction and expansion of nuclear facilities and facilities related to their operation; takes part in state monitoring of design and construction of nuclear facilities (structures) in the manner prescribed by the Government of the Republic of Lithuania; issues licences for the use of natural resources, organises state radio-ecological monitoring, co-ordinates and controls radiological monitoring of nuclear facilities; organises and co-ordinates scientific research of the impact of nuclear facilities on the environment; periodically informs the public, national and local authorities about the radiation situation in the country and in the environment of nuclear facilities; by the advise of nuclear facilities' state control and supervision bodies or at its own initiative cancels a licence to construct or reconstruct a nuclear facility, when it is found that such licence has been issued illegally.

At the end of each month the power plant operator provides monthly data on pollution (except data on H-3, which is submitted every three months) to the Environmental

Protection Agency, the Radiation Protection Centre and VATESI. The power plant operator submits the annual monitoring report to the Ministry of Environment, the Environmental Protection Agency, Radiation Safety Center, VATESI and the local municipal authorities which territory accommodates the nuclear facility. The monitoring report shall include:

- Results of all measurements foreseen in the Monitoring Program and their analysis;
- Activities of radionuclides released into ambient air and water (by months) and total annual activities of radionuclides;
- General information concerning realized activities (amount of produced electricity, radioactive waste, generated, conditioned, stored or disposed by the nuclear facility);
- Comparison of released radionuclide activities with the activity limits, the value of normalised contamination;
- Alternation trends of releases and contamination, as well as their analysis;
- Evaluative doses to the members of critical groups due to annual radionuclide releases (per radionuclide, per radionuclide flow, per group of radionuclides, as well as total dose of the nuclear facility), their comparison with the dose constraint;
- Reasons of extraordinary releases of radionuclides into the environment and their analysis;
- Any other important information.

The *Law on Radiation Protection* establishes the legal basis for protection of people and the environment from the harmful effects of ionising radiation. The law also establishes a licensing system for the use of radioactive materials and radiation-emitting devices, and prescribes general rules for their use.

According to the *Law on Radiation Protection*, the Radiation Protection Centre (RPC) under the Ministry for Health Care is the regulatory body which coordinates activities of other public institutions and local government in the field of radiation protection, monitoring and expert examination of public exposure. Also the RPC is responsible for the radiation protection of workers and the public from negative impacts arising during operation and decommissioning of nuclear facilities.

The main documents regulating radiation protection requirements at nuclear facilities are:

- *Lithuanian Hygiene Standard HN 73:2001* "Basic Standards of Radiation Protection";
- *Lithuanian Hygiene Standard HN 87:2002* "Radiation Protection in Nuclear Facilities";
- *Lithuanian Hygiene Standard HN 99:2000* “Protective Actions of Public in Case of Radiological or Nuclear Accident”.

The power plant operator is required to submit to the Ministry of Health Care annual and quarterly reports on personnel exposure, reports on cases for which the maximum permissible levels of radiation exposure were exceeded and occupational diseases.

The Ministry of Social Security and Labour is responsible for the supervision of potentially dangerous equipment (cranes, pipelines, vessels) through the Services of Technical Verification, except for that subject to inspection by VATESI, according to the *Law on the supervision of potentially dangerous technical installations*.

The Ministry of Social Security also checks adherence to labour protection requirements set in laws regulating labour relations and other regulations. The power plant operator is expected to report to the State Labour Inspection all cases of industrial accidents and send annual reports on industrial safety.

The Ministry of Transport and Communications take part in drafting laws and subordinate legislation regulating transportation of nuclear and radioactive materials; participates in training and certification of the personnel involved in transportation of nuclear and radioactive materials; organises railway transport for the evacuation of the population from the danger zone in the event of a nuclear accident.

The Ministry of National Defence takes part in drafting and implementing co-ordinated interdepartmental anti-terrorist and anti-penetration protection plans of the nuclear power plant and other nuclear facilities; participates in ensuring of the physical protection of nuclear facility.

The Ministry of Interior assures fire protection of the nuclear power plant and other nuclear facilities, lays down fire protection requirements for nuclear facilities, promptly extinguishes fires breaking out at nuclear facilities, participate in the management of a nuclear accident and its consequences, provides assistance in ensuring physical protection of a nuclear power plant and the safety of transportation of nuclear and radioactive materials in the territory of the country, drafts, co-ordinates and implement interdepartmental anti-terrorist and anti-penetration action plans, analyses and controls the crime situation in the regions with nuclear facilities.

According to the National *Law on Civil Defence*, the Fire Protection and Rescue Department performs the following activities:

- Implements the State supervision requirements for fire safety at nuclear power plant and organises the extinguishment of fires;
- organises accident mitigation activities for nuclear power plants in case of nuclear accidents which can be rated to 5, 6 or 7 level according to INES scale;
- co-ordinates activities of all institutions involved in accident mitigation at nuclear power plants;
- periodically reports to the President, Parliament and Government on the progress in accident mitigation;
- implements Governmental decisions and instructions related to the accident;
- organises public evacuation from the affected area;
- informs interested organisations, mass media, general public on accident mitigation measures and the risk of ionising radiation, etc.

The Governmental Emergencies Commission:

- proposes to the Prime Minister the candidacy of the head of civil defence operation for the leadership of the elimination activities of a nuclear accident and its consequences;
- mobilizes material and other resources necessary for the elimination of a nuclear accident.

Governor of the county on the territory whereof the construction of a nuclear facility is planned or has already started, participates in exercising supervision and control of the facility and acts within the limits of the powers delegated to him by the *Law on the County Government* and other legal acts.

Requirements for emergency preparedness and response actions in case of accidents at the new NPP and existing emergency preparedness of Ignalina NPP are described in Section 10.5.

5.3.4 Implementation of the safety requirements for a new NPP

As discussed above the designs of all Generation III+ design and some Generation II and III designs incorporate high safety goals. It is a requirement of the new nuclear power plant that the possibility of an accident leading to reactor core damage is less than 10^{-5} per year and large environmental radioactive releases occur less than 10^{-6} per year. All candidate reactor plants being considered meet these requirements by a significant margin. As well as the being designed to withstand severe accidents caused by core melting, the plant must also be designed to withstand external threats such as a crash of airplane (aircraft) defined in the requirements, external natural events (earthquake or extreme winds). Also for the safe NPP operation the physical protection system shall be installed. This system allows to prevent internal and (or) external threats for example, due to sabotage or terrorist attack, which are defined in the design of nuclear facilities.

The decision regarding the new reactor plant type will be made after this Environmental Impact Assessment Report on the basis of a number of factors including plant safety, plant efficiency and fuel efficiency/economics. The present physical security and protection measures and existing emergency preparedness at the Ignalina can be used to support a new nuclear power plant build. However, the new emergency preparedness plan will be developed by the operator of the new NPP.

<u>Reports to be made in further developing the project</u>

The Environmental Impact Assessment (EIA) procedure of the proposed new power plant will be followed by a Government Resolution application in accordance with Lithuanian Law and due process. When applying for Resolution neither the plant supplier nor the project safety standards and criteria *in detail* will have been chosen, hence the decision will focus on the safety goals described in the legal acts of VATESI and IAEA safety standards. If the Resolution is favourable and Parliament ratifies it, negotiations will commence with the plant suppliers.

Once the selection of a plant has been achieved, work can then start on the preliminary safety analysis report which on completion will be submitted to VATESI in order to obtain a construction licence. This safety report will include detailed plant type-specific safety assessments to demonstrate the integral safety of the design, relevant limits and conditions for safe operation and maintenance, and suitable management arrangements of the operating company and site staff. In addition to the computational analysis describing accidents, probabilistic risk assessments will also be included covering the likelihood of different events e.g. the frequency of core damage and off-site radioactive releases.

Once the construction license has been obtained a final safety analysis report will be required in order to obtain an operating license. A condition for granting the operational license is that during construction, the safety analyses are updated to reflect any changes arising due to design changes. Such change proposals will be subject to power plant developer approval and where appropriate submitted to the appropriate authority before the change can be accepted. Commissioning tests will prove the performance of plant and systems in a progressive manner, prior to permission to begin commercial operations. Plans for the physical protection, prevention of nuclear and radiological accidents, emergency response arrangements in case of these accidents and a quality management program for operation must be prepared before the operation of new NPP. Moreover, environmental permits shall be obtained (e.g., authorisation of release of radionuclides, permission of integrated pollution prevention and control) and environmental monitoring program shall be prepared, etc.

According to the provisions of „Description of the Order of Presentation of Data on Activities Related to Radioactive Waste Disposal to the Commission of European Communities (*State Journal, 2007, No. 55-2141*), which implement the conditions of Article 37 of the European Atomic Energy Community (Euratom) Treaty and take into account the Commission recommendation 1999/829/Euratom of December 6, 1999 on the application of Article 37 of the Euratom Treaty, the nuclear operator shall provide the European Commission with general information on the activities related to radioactive waste disposal, during which the water, soil or air can be contaminated with radionuclides.

5.4 PROCUREMENT OF FUEL

5.4.1 Availability of nuclear fuel

Typically a new power plant consumes annually as fuel circa 30 tons of enriched uranium, which requires 200 tons of natural uranium. The exact amount of fuel assemblies and uranium inside the nuclear reactor is dependent on the reactor type and its size. Nuclear power plants usually have their own fuel storages which normally contain fuel for one year consumption.

Nuclear fuel manufacturing can be divided into four different phases which are: mining, milling and concentrating the uranium reaching the form of U_3O_8 (or yellowcake), typically sold in international markets; its conversion to gaseous form in uranium hexafluoride (UF_6), the enrichment increasing the percentage of isotope U-235 and at the end the production of the fuel assemblies utilising uranium dioxide UO_2 derived from the enrichment process. The production chain of nuclear fuel is described more in detail in the next sections of this chapter.

The global total demand for natural uranium in 2006 was around 62 000 tons supplying a total nuclear production capacity of more than 370 GW_e. According to the 2007 World Nuclear Association's (WNA) basic scenario, nuclear production capacity will increase in the next years to around 520 GW_e in 2030 *(Kwasny, 2007; WNA, 2007)*.

At the moment, natural uranium (uranium produced from mining) covers two thirds of the total nuclear fuel demand. The rest of the uranium for the nuclear fuel comes from military sources, uranium storages and from the re-enrichment of the depleted uranium. Moreover, in some countries part of the spent nuclear fuel is reprocessed and utilised again. This process is not allowed in different countries including Lithuania.

In 2007, the production volume of natural uranium was just above 40 000 tons (Figure 5.4-1). In the same year, the biggest manufacturing countries for natural uranium were Canada (25 %), Australia (19 %) and Kazakhstan (13 %). Other important countries in the uranium business are Russia, some African countries, Uzbekistan and USA. In 2007, the 12 biggest manufacturing countries produced 98 % of the natural uranium produced worldwide*)*.

The biggest companies specialised in natural uranium mining are Cameco (Canada) Rio Tinto (Australia) and AREVA (France), which together mined out more than 50 % of the world's natural uranium in 2007. The world's biggest site for uranium extraction, named Key Lake/Mc Arthur River and controlled by Cameco, is located in Canada, and in 2007 produced 7200 tons of natural uranium (17 %) of the total production worldwide.

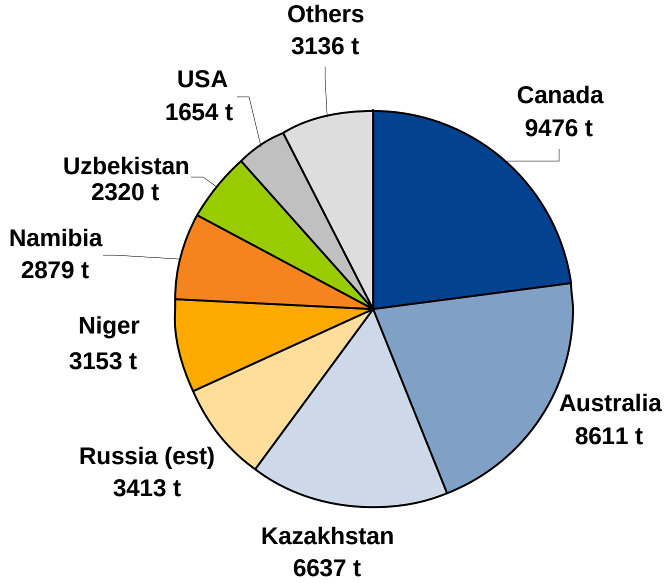


Figure 5.4-1. Uranium production from mines per country in 2007; in total 41 279 tU (*WNA, 2008e*).

At the moment, the technically and economically feasible uranium resources available amount to 4.7 million tons. In addition, it is estimated that some 10 million tons of uranium resources can be utilised with existing technologies. It has been forecasted that these resources are consistent enough to cover the international demand also in the next decades, despite the increase in generation capacity from nuclear installations *(OECD and IAEA, 2006).*

During the last years, the price of uranium has increased remarkably. This has led to several new uranium explorations around the world, new mines have already been started while continuing operations in some old mines now dismissed are under consideration.

Nowadays, there are 8 uranium conversion installations around the world, with conversion plants located in France, Great Britain, Russia, USA, Canada, China and Argentina *(IAEA databases, 2008)*, with different sizes and technical characteristics, tailor made for the reactor types used in the country and the international market need.

There are more countries involved worldwide in uranium enrichment, including also Germany, Japan, the Netherlands and Pakistan *(IAEA databases, 2008)*. The different enrichment levels of the different installations also depend on the reactor characteristics and on the market needs.

The manufacturing of the fuel assemblies is finalised in several countries in addition to those previously mentioned, including also Belgium, Brazil, Germany, India, Japan, Kazakhstan, Pakistan, Romania, South Korea, Spain and Sweden (*IAEA databases, 2008*). It is a process strongly dependent on the plant type. At the moment, there is over capacity in fuel assembly manufacturing which means that in the near future there will not be any shortage in the production processes.

Since 1992, the EU has maintained strict quantitative restrictions on imports of enriched uranium to protect its domestic producers. Since 1994, these restrictions have been applied in accordance with the terms of the Corfu Declaration, a joint European Council and European Commission policy statement that has never been made public or notified to the WTO. The Corfu Declaration appears to impose explicit quotas on imports of enriched uranium, limiting imports to only about 20 percent of the European market.

Since 1994, when the Declaration of Corfu was signed, 12 new members, mostly from Eastern Europe, have joined the EU, and many of these countries operate Russian-designed reactors that are 100 % supplied with fuel from Russia. In reality today 35-40 % of the uranium used in EU countries comes from non-EU sources due to the Eastern European nuclear power plants which are fully dependent on Russian fuel. Recently, the Russians have opened discussions on the EU quota with the European Commission (EC).

Neither natural uranium production, nor conversation or transportation will take place in Lithuania. Also nuclear fuel production it is not planned in Lithuania. Only transportation of nuclear fuel is planned. Fuel assemblies to the new NPP will be delivered per rail or other overland routes; it depends from which country fuel assemblies will be bought. Transportation of nuclear fuel in special packages will be in accordance to the requirements of national and international legal acts.

5.4.2 Mining and purification of uranium

In 2006, 41 % of total production of natural uranium was obtained from underground mines, 24 % from opencast mines and 26 % using underground leaching; 9 % of the total production of uranium was obtained as by-products of other mining products such as copper and gold *(WNA, 2007).*

In traditional mines, the ore is extracted from the bedrock, crushed and ground. The rock material is then usually treated with sulphuric acid at a separate mill in order to separate uranium from it (milling process). In general 75 – 90 % of the total volume of uranium content in the ore can be utilized. After this the uranium is further separated with several solvents and precipitated with ammonia. The result is U_3O_8 (triuranium oxide) which is called uranium concentrate (yellowcake).

In the in-situ leaching method (ISL) holes, through which acid or alkaline solution is circulated, are drilled in the ground. Uranium mineral dissolves into circulated solution from which the uranium is extracted at the ground level mill. The solution is processed, depending on the acidity of the groundwater, either with the method of solution extraction or ion exchangers. The uranium concentrate (U_3O_8) produced in the precipitation phase is dried in at high temperature. There are ISL mines in for instance Kazakhstan, the USA and Australia. *(WNA, 2008b)*

Environmental impacts of the uranium mine activity are related to radiation impacts of the uranium ore, radiation impacts of radon gas released from the ore, waste from mining and waste water.

In many respects uranium mining is much the same as any other mining. Projects must have environmental approvals prior to commencing, and must comply with all environmental, safety and occupational health conditions applicable. Increasingly, these are governed by international standards, with external audits (*WNA 2008f*).

Once approved, open pits or shafts and drives are dug, waste rock and overburden is placed in engineered dumps. Tailings from the ore processing must be placed in engineered dams or underground. Air and water pollution must be avoided. Run-off from the mine stockpiles and waste liquors from the milling operation are collected in secure retention ponds for isolation and recovery of any heavy metals or other contaminants. The liquid portion is disposed of either by natural evaporation or recirculation to the milling operation. For instance most Australian mines adopt a "zero discharge" policy for any pollutants (*WNA 2008f*).

Process water discharged from the mill contains traces of radium and some other metals which would be undesirable in biological systems downstream. This water is evaporated and the contained metals are retained in secure storage. During the operational phase, such water may be used to cover the tailings while they are accumulating. Finally the whole site must be rehabilitated at the end of the project (*WNA 2008f*).

These processes are common to all metalliferous mining, and are well recognised and understood.

In the case of in situ leach (ISL) mining, there is much less disturbance - simply multiple boreholes, and rehabilitation is simpler.

With in situ leach (ISL) operations, the orebody stays in the ground and uranium is recovered by circulating oxygenated and acidified groundwater through it, using injection and recovery wells. The saline quality of this groundwater in Australian ISL mines makes it far from potable in the first place, and after the uranium is recovered, oxygen input and circulation are discontinued, leaving the groundwater much as it was (*WNA 2008f*).

The main environmental consideration with ISL is avoiding pollution of any groundwater away from the orebody, and leaving the immediate groundwater no less useful than it was initially.

While uranium itself is only slightly radioactive, radon, a radioactive inert gas, is released to the atmosphere in very small quantities when the ore is mined and crushed. Radon is one of the decay products of uranium and radium, and occurs naturally in most rocks - minute traces of it are present in the air which we all breathe (*WNA 2008f*).

Open cut mines are naturally well ventilated. Underground mines are ventilated with powerful fans. Radon levels are kept at a very low and certainly safe level in uranium mines. (Radon in non-uranium mines also may need control by ventilation.)

Dust is suppressed in the mines, since it represents the main potential exposure to alpha radiation as well as a gamma radiation hazard.

At any mine, designated employees (those likely to be exposed to radiation or radioactive materials) are monitored for alpha radiation contamination and personal dosimeters are worn to measure exposure to gamma radiation. Routine monitoring of air, dust and surface contamination is undertaken (*WNA 2008f*).

Nowadays in countries where uranium mining is practised (such as Canada and Australia) the processes related to upgrading of mines and uranium are governed by regulations and guidelines of National Administration and both Environmental and Nuclear Safety Authorities, which are strictly supervising the mining operations. The state of the environment is monitored for several years after shutting down the activity and even after the restoring activities in the mining area. Environmental, health and safety issues related to mining activities are increasingly controlled by international standards and external audits.

5.4.3 Conversion and enrichment

Before enrichment, the uranium is converted in gaseous form through chemical processes to uranium hexafluoride (UF_6). In this process called conversion different chemicals and heat energy are used.

In natural uranium the share of the isotope U-235, needed in fission reactors for its ability to cause a rapidly expanding fission chain reaction, is only 0.7 %. The remaining 99.3 % is mostly U-238. In common Light Water Reactors the share of U-235 of the uranium is approximately 3.5 %. The enrichment of uranium hexafluoride is executed either by gas diffusion or nowadays increasingly by centrifuge methods by utilizing chemical and physical characteristic of the uranium. Energy consumption of the centrifuge methods is substantially lower than of gas diffusion.

Only 15 % of the original amount of uranium is transformed into enriched uranium at the end of the enrichment process, while 85 % is so called residual uranium. The residual uranium can be used to some extent in certain types of reactors and the uranium originating from the military use can be used diluted in civil reactors.

The conversion and enrichment processes are classified under chemical industry where hazardous chemicals are used, treated and stored. These operations are governed by several international and national regulations regarding the management of hazardous chemicals and waste.

5.4.4 Production of nuclear fuel

The production stages of nuclear fuel consist of the conversion of enriched uranium hexafluoride to uranium oxide, the production of pellets and the production of fuel rods.

The uranium oxide is converted to ceramic and pressed into pellets 1.5 and 2 centimetres in diameter. The fuel pellets are placed into tubes made of a zirconium compound or stainless steel around 4 meters long. Several fuel rods are afterwards composed in fuel assemblies approximately 30 centimetres in diameter.

The radiation impacts of the production stages in a fuel plant are not significant. However several hazardous chemicals are handled in the fuel plant. The handling processes are executed according to laws and regulations for the handling and storage of hazardous chemicals.

5.4.5 Reprocessing of spent nuclear fuel

The so called PUREX process (Plutonium URanium EXtraction) is at present the most developed and widely used process in re-processing plants. The fuel is dissolved into nitric acid and uranium and plutonium are separated chemically using solvents during the chemical process. The gained plutonium can be used as such in the production of MOX fuel (Mixed Oxide), whereas the recycling of uranium into fuel requires a re-enrichment process. The recovery of uranium's energy through reprocessing of spent nuclear fuel amounts to 30 %. Correspondingly, relevant amounts of untreated natural uranium are saved and, in addition, the overall amounts of strongly radioactive waste decrease.

The reprocessing option is still under discussion in the international community because of doubts of its economic feasibility and its strict interconnection with the production and disposal of nuclear weapons.

5.4.6 Transports and storage in the nuclear fuel production chain

The slightly radioactive ***enriched natural uranium*** is packed into barrels, loaded into containers and transported by ship or train to intermediate storage and the conversion plant. The steel transport containers offer adequate radiation protection. The transport only requires stock suitable for transporting hazardous materials.

The uranium hexafluoride from the conversion is packed into special containers, which also function for storage, and is transported to the enrichment plant by train or by trucks. Uranium hexafluoride is a highly chemically-toxic substance and appropriate precautionary measures are applied in transports. Uranium hexafluoride has been transported in considerable amounts for decades. There have been accidents in truck, railroad and ship transports. The accidents that have taken place have not resulted in releases of uranium hexafluoride in amounts that would have caused harmful environmental impacts.

The enriched uranium, which is in solid form, is packed into containers, similar to those used when transporting it to the enrichment plant. Enriched uranium is transported to the fuel plant by train or by truck. The transport container is protected to endure any fire during an accident, for example. The enriched uranium is only slightly water soluble, which limits the emergence of environmental impacts in case of a shipping accident. Depleted uranium, the by-product from enriching uranium, is stored in containers similar to those used for transporting natural uranium hexafluoride. Radiation is not the primary hazard of depleted uranium poses to human health under most exposure scenarios. Though irradiation from DU can occur, chemical toxicity is usually the major hazard.

Fresh nuclear fuel elements are packed into special packages that protect the fuel elements during transport. Fuel elements are transported to the nuclear power plant by train or by trucks. Due to the low radioactivity of fresh nuclear fuel elements, special radiation protection is not necessary. The criticality risk associated with the material, i.e. the risk of a nuclear reaction starting, is prevented by the design of the package, the arrangement of the fuel assemblies within the package, limitations on the amount of material contained within the package, and by the number of packages carried in one shipment.

The annual amount of fuel and spent nuclear fuel in nuclear power plants is low comparing with other fuel based power production plants. For this reason, the volume of transports is relatively low. However transports are needed in several stages of the production chain, distances can be long and the material to deliver can be hazardous or radioactive. Some companies working for nuclear power plants are specialised in the transportation of nuclear fuel and other hazardous and radioactive materials.

Intermediate products and fuel compositions transported from mines to the power plant are only slightly radioactive. However, some of these materials (like uranium hexafluoride transported from the conversion plant to the enrichment plant) are chemically strongly toxic substances and special packages and strict safety requirements defined according international agreements and internal transportation regulations are applied during transportation.

The main national legal acts and IAEA safety standards and requirements for transportation and storage of radioactive materials are as follows:

- Regulations on the import, export, transit and internal transport of radioactive materials, radioactive waste and spent nuclear fuel in Republic of Lithuania (State News, 2009-01-10, No. 3-64)
- Regulations on the acceptance of the certificate of conformance issued by foreign authorities for transportation packages of radioactive materials and radioactive waste (State News, 2008-11-25, No. 135-5295)
- Regulations for the Safe Transport of Radioactive Material 2005 Edition, Safety Requirements No. TS-R-1.

- Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material, IAEA Safety Standards Series No. TS-G-1.2 (ST-3).

The purpose of the regulations is to protect people and the environment from radiation during transportation of radioactive materials.

6 WASTE

The Law on Waste Management of the Republic of Lithuania (*State Journal, 2002, No. 72-3016*) sets out general requirements for waste prevention, accounting, collection, storage, transportation, utilisation, and disposal to avoid negative effects on human health and the environment, as well as the main guideline of organisation and planning of waste management systems. This Law does not regulate pollutant emissions into air, discharge into water and radioactive waste management.

The Rules on the Issue, Update and Cancelation of Permissions of Integrated Pollution Prevention and Control (*State Journal, 2005, No. 103-3829; 2006, No. 120-4571*) set out the order of the issue, update and cancelation of a permission to operate objects of an economic activity or to exercise an economic activity, indicated in the Law on Environmental Protection of the Republic of Lithuania (*State Journal, 1992, No. 5-75; 2008 No. 120-4550*), as well as implementation of the means of waste prevention, provided by the Law on Waste Management (*State Journal, 2002, No. 72-3016*). These Rules establish the Integrated Pollution Prevention and Control System that consolidates means on protecting water, air, soil (including geology), as well as waste management and noise reduction. According to Clause 11.5 of these Rules, waste production shall be avoided. When waste is produced it shall be managed by reprocessing, and in case this is impossible from technical and economical point of view waste is managed with the aim to avoid detrimental effects on the environment or to reduce them.

The Rules of Waste Management (*State Journal, 2004, No. 68-2381; 2007, No. 11-461*) set out the order of waste collection, storage, transportation, utilisation, disposal, accounting, identification, declaration, sorting and marking. Waste utilisation and disposal, employing methods not indicated in these Rules is prohibited. According to Clause 5.2 of these Rules, “waste” shall mean any substance or object which the holder of waste discards or intends or is required to discard and which belong to the categories set out in Annex I of these Rules and are listed in the List of Waste, given in Annex 2 of these Rules. According to Clause 47 of these Rules, enterprises that hold the Permit of the Integrated Pollution Prevention and Control shall collect the waste indicated in the Permit separately and transfer to waste utilization and/or disposal companies, appointed by this Permit, for handling. According to Clause 52 of these Rules, a producer of hazardous waste shall identify hazardous waste that he possesses, evaluate its composition and declare its production in an application for obtainment of a Permit of the Integrated Pollution Prevention and Control.

6.1 CONSTRUCTION OF THE NUCLEAR POWER PLANT

During the construction of the new NPP all possible and economically justified measures to minimize waste generation, as well as to reduce detrimental impact on human health and the environment will be implemented. Preventive measures to minimize waste generation will be employed, the amount of waste getting into dumps, as well as its harmfulness will be reduced, low-waste technologies will be introduced, and natural resources will be saved.

The waste produced during construction of the NNPP will be sorted and temporally stored on site in such a manner that it will not produce adverse impacts on human health and the environment. Then the waste will be transferred to waste handling (collecting, transporting, storing, utilising and disposing) companies registered under the conditions laid down by the Government or its authorised body. According to Clause 8, part 3 of the Law on Waste Management (*State Journal, 2002, No. 72-3016*) hazardous waste shall be stored on site for a maximum duration of 3 months, and non-hazardous – for a maximum duration of 1 year from its production. Hazardous waste will be transferred to companies that handle (collect, transport, store, dispose or utilise) hazardous waste and that hold licenses, issued under the conditions laid down by the Government or its authorised body. According to Clause 12, part 2 of the Law on Waste Management (*State Journal, 2002, No. 72-3016*) the license shall indicate types of hazardous waste that can be handled by the license holder and handling methods for this waste.

Estimated time of the construction of a new NPP is 4-7 years. No radioactive waste is foreseen to be generated during this period. An environmental audit of the sites will be carried out prior to selection of the site to be used to ensure this. This audit will cover both radiological and non-radiological issues and it will include soil sampling and analysis. The non-radioactive waste produced during the stage of the construction of a new NPP will be non-hazardous waste (waste gravel and crushed rocks, waste sand and clays, concrete, bricks, metals, ceramics, wood, glass, plastic, and bituminous mixtures; waste from production of building structures and welding, packaging of various equipment; cables; insulation materials; mixed construction waste, territory-cleaning residues, etc.), as well as environmentally hazardous waste (waste paint and varnish, waste adhesives and sealants containing organic solvents or other dangerous substances; coal tar and tarred products, batteries and accumulators, absorbents, wiping cloths, contaminated by petroleum products, etc.). According to the preliminary estimation during the whole construction stage of one 1600/1700 MW power reactor approximately 14 500 tones (including about 870 tonnes, i.e. about 6 % of hazardous waste), and during the whole construction stage of two 1600/1700 MW power reactors about 27 000 tonnes of waste will be produced (including about 1470 tonnes, i.e. about 5.4 % of hazardous waste). Potential amounts of waste, produced during the construction of the new NPP, waste aggregative state, code pursuant to the Waste List, hazardousness, conditions of waste storage at the site and proposed waste management methods are given in Table 6.1–1. A more precise list of waste being produced, its amounts, management methods etc. can only be clarified as the project proceeds, when reactor type and number, final layout on the site and other parameters are known. More accurate data on waste production, storage and management can be declared only in an application for obtainment of a Permit of the Integrated Pollution Prevention and Control.

Table 6.1–1. Waste that will be produced during the construction stage of the new NPP and waste management.

Waste						Waste storage at site		Proposed methods of waste management
Name	Total amount for 1 1600/1700 MW power reactor, tonnes	Total amount for 2 1600/1700 MW power reactors, tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
Waste gravel and crushed rocks	60	120	Solid	01 04 08	Non-hazardous	At open site	10	Transfer to waste handling companies
Waste sand and clays	60	120	Solid	01 04 09	Non-hazardous	At open site	10	Transfer to waste handling companies
Waste paint and varnish containing organic solvents or other dangerous substances	1	2	Liquid	08 01 11*	H14 ecotoxic	In tanks	0.2	Transfer to hazardous waste handling companies
Waste paint and varnish other than those mentioned in 08 01 11	0.8	1.6	Liquid	08 01 12	Non-hazardous	In tanks	0.1	Transfer to waste handling companies
Wastes from paint or varnish removal containing organic solvents or other dangerous substances	0.5	1	Liquid	08 01 17*	H14 ecotoxic	In tanks	0.1	Transfer to hazardous waste handling companies
Wastes from paint or varnish removal other than those mentioned in 08 01 17	0.2	0.4	Liquid	08 01 18	Non-hazardous	In tanks	0.1	Transfer to waste handling companies
Waste paint or varnish remover	0.2	0.4	Liquid	08 01 21*	H14 ecotoxic	In tanks	0.1	Transfer to hazardous waste handling companies
Waste coating powders	1	2	Solid	08 02 01	Non-hazardous	In containers	0.2	Transfer to waste handling companies
Waste adhesives and sealants containing organic solvents or other dangerous substances	3	6	Paste	08 04 09*	H14 ecotoxic	In containers	0.3	Transfer to hazardous waste handling companies
Waste adhesives and sealants other than those mentioned in 08 04 09	40	40	Paste	08 04 10	Non-hazardous	In containers	5	Transfer to waste handling companies
Waste ceramics, bricks, tiles and construction products	500	1000	Solid	10 12 08	Non-hazardous	At open site	100	Transfer to waste handling companies
Ferrous metal filings and turnings	40	80	Solid	12 01 01	Non-hazardous	In containers	5	Transfer to waste handling companies
Non-ferrous metal filings and turnings	2	4	Solid	12 01 03	Non-hazardous	In containers	0.3	Transfer to waste handling companies

Waste						Waste storage at site		
Name	Total amount for 1 1600/1700 MW power reactor, tonnes	Total amount for 2 1600/1700 MW power reactors, tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	Proposed methods of waste management
Plastics shavings and turnings	2	4	Solid	12 01 05	Non-hazardous	In containers	0.3	Transfer to waste handling companies
Mineral-based machining oils free of halogens (except emulsions and solutions)	10	20	Liquid	12 01 07*	H14 ecotoxic	In tanks	1	Transfer to hazardous waste handling companies
Synthetic machining oils	2	4	Liquid	12 01 10*	H14 ecotoxic	In tanks	0.2	Transfer to hazardous waste handling companies
Welding wastes	10	20	Solid	12 01 13	Non-hazardous	In containers	1	Transfer to waste handling companies
Spent grinding bodies and grinding materials other than those mentioned in 12 01 20	2	4	Solid/ Liquid	12 01 21	Non-hazardous	In containers	0.3	Transfer to waste handling companies
Other engine, gear and lubricating oils	3	6	Liquid	13 02 08*	H14 ecotoxic	In tanks	0.3	Transfer to hazardous waste handling companies
Other insulating and heat transmission oils	10	20	Liquid	13 03 10*	H14 ecotoxic	In tanks	10	Transfer to hazardous waste handling companies
Other emulsions (aqueous and oil emulsion containing turbine, transformer and other oils)	150	300	Liquid	13 08 02*	H14 ecotoxic	In tanks	15	Transfer to hazardous waste handling companies
Other halogenated solvents and solvent mixtures	0.5	1	Liquid	14 06 02*	H14 ecotoxic	In tanks	0.1	Transfer to hazardous waste handling companies
Other solvents and solvent mixtures	0.5	1	Liquid	14 06 03*	H14 ecotoxic	In tanks	0.1	Transfer to hazardous waste handling companies
Paper and cardboard packaging	30	60	Solid	15 01 01	Non-hazardous	In containers	2	Transfer to waste handling companies
Plastic packaging	50	100	Solid	15 01 02	Non-hazardous	In containers	5	Transfer to waste handling companies
Wooden packaging	50	100	Solid	15 01 03	Non-hazardous	In containers	5	Transfer to waste handling companies
Metallic packaging	60	120	Solid	15 01 04	Non-hazardous	In containers	10	Transfer to waste handling companies
Composite packaging	50	100	Solid	15 01 05	Non-hazardous	In containers	5	Transfer to waste handling companies

Waste						Waste storage at site		
Name	**Total amount for 1 1600/1700 MW power reactor, tonnes**	**Total amount for 2 1600/1700 MW power reactors, tonnes**	**State of aggregation (solid, liquid, paste)**	**Code according to the Waste List**	**Hazardousness**	**Storage conditions**	**Maximum amount, tonnes**	**Proposed methods of waste management**
Mixed packaging	150	300	Solid	15 01 06	Non-hazardous	In containers	10	Transfer to waste handling companies
Glass packaging	2	4	Solid	15 01 07	Non-hazardous	In containers	0.4	Transfer to waste handling companies
Packaging containing residues of or contaminated by dangerous substances	1	2	Solid	15 01 10*	H14 ecotoxic	In containers	0.1	Transfer to hazardous waste handling companies
Absorbents, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated by dangerous substances (petroleum products)	10	20	Solid/ Liquid	15 02 02*	H14 ecotoxic	In containers	1	Transfer to hazardous waste handling companies
Absorbents (sawdust, sand, contaminated by petroleum products)	4	8	Solid/ Liquid	15 02 02*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
Absorbents, filter materials, wiping cloths and protective clothing other than those mentioned in 15 02 02	70	140	Solid	15 02 03	Non-hazardous	In containers	10	Transfer to waste handling companies
End-of-life tyres	10	20	Solid	16 01 03	Non-hazardous	In garage	1	Transfer to waste handling companies
End-of-life vehicles	50	100	Solid/ Liquid	16 01 04*	H14 ecotoxic	In garage	10	Transfer to hazardous waste handling companies
Oil filters	4	8	Solid/ Liquid	16 01 07*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
Brake pads other than those mentioned in 16 01 11	0.5	1	Solid	16 01 12	Non-hazardous	In containers	0.1	Transfer to waste handling companies
Brake fluids	0.3	0.6	Liquid	16 01 13*	H14 ecotoxic	In tanks	0.1	Transfer to hazardous waste handling companies
Antifreeze fluids containing dangerous substances	0.5	1	Liquid	16 01 14*	H14 ecotoxic	In tanks	0.1	Transfer to hazardous waste handling companies
Tanks for liquefied gas	2	4	Solid	16 01 16	Non-hazardous	In warehouse	0.3	Transfer to waste handling companies
Discarded equipment containing hazardous	60	100	Solid	16 02 13*	H14 ecotoxic	In warehouse	10	Transfer to hazardous

Waste						Waste storage at site		
Name	**Total amount for 1 1600/1700 MW power reactor, tonnes**	**Total amount for 2 1600/1700 MW power reactors, tonnes**	**State of aggregation (solid, liquid, paste)**	**Code according to the Waste List**	**Hazardousness**	**Storage conditions**	**Maximum amount, tonnes**	**Proposed methods of waste management**
components other than those mentioned in 16 02 09 to 16 02 12 (hazardous components of electrical and electronic equipment can contain accumulators and batteries mentioned in 16 06 and marked as dangerous; mercury-switches, cathode ray tubes and other activated glass, etc.)								waste handling companies
Discarded equipment other than those mentioned in 16 02 09 to 16 02 13 (details and components of equipment, insulators of glass and porcelain)	100	150	Solid	16 02 14	Non-hazardous	In containers	10	Transfer to waste handling companies
Inorganic wastes containing dangerous substances	4	8	Solid	16 03 03*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
Inorganic wastes other than those mentioned in 16 03 03	10	20	Solid	16 03 04	Non-hazardous	In containers	1	Transfer to waste handling companies
Laboratory chemicals, consisting of or containing dangerous substances, including mixtures of laboratory chemicals	15	25	Solid/ Liquid	16 05 06*	H14 ecotoxic	In warehouse/ In tanks	3	Transfer to hazardous waste handling companies
Lead batteries	6	12	Solid	16 06 01*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
Alkaline batteries (except 16 06 03)	6	12	Solid	16 06 04	Non-hazardous	In containers	0.5	Transfer to waste handling companies
Other batteries and accumulators	2	4	Solid	16 06 05	Non-hazardous	In containers	0.2	Transfer to waste handling companies
Wastes containing oil (waste from cleaning transport tanks and drums)	100	150	Liquid	16 07 08*	H14 ecotoxic	In tanks	10	Transfer to hazardous waste handling companies
Concrete	2000	3500	Solid	17 01 01	Non-hazardous	In containers	200	Transfer to waste handling companies
Bricks	50	80	Solid	17 01 02	Non-hazardous	In containers	10	Transfer to waste handling companies

Waste						Waste storage at site		Proposed methods of waste management
Name	Total amount for 1 1600/1700 MW power reactor, tonnes	Total amount for 2 1600/1700 MW power reactors, tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
Tiles and ceramics	10	20	Solid	17 01 03	Non-hazardous	In containers	2	Transfer to waste handling companies
Wood	1000	1700	Solid	17 02 01	Non-hazardous	In containers	100	Transfer to waste handling companies
Glass	60	120	Solid	17 02 02	Non-hazardous	In containers	5	Transfer to waste handling companies
Plastic	10	20	Solid	17 02 03	Non-hazardous	In containers	1	Transfer to waste handling companies
Bituminous mixtures other than those mentioned in 17 03 01	10	16	Solid/ Paste	17 03 02	Non-hazardous	In containers	1	Transfer to waste handling companies
Coal tar and tarred products	400	600	Solid/ Paste	17 03 03*	H14 ecotoxic	In containers	50	Transfer to hazardous waste handling companies
Copper, bronze, brass	4	8	Solid	17 04 01	Non-hazardous	In containers	0.5	Transfer to waste handling companies
Aluminum	140	280	Solid	17 04 02	Non-hazardous	In containers	15	Transfer to waste handling companies
Lead	10	20	Solid	17 04 03	Non-hazardous	In containers	1	Transfer to waste handling companies
Iron and steel	1000	2000	Solid	17 04 05	Non-hazardous	In containers	200	Transfer to waste handling companies
Mixed metals	2000	4000	Solid	17 04 07	Non-hazardous	In containers	300	Transfer to waste handling companies
Cables other than those mentioned in 17 04 10	40	80	Solid	17 04 11	Non-hazardous	In containers	5	Transfer to waste handling companies
Soil and stones other than those mentioned in 17 05 03	100	140	Solid	17 05 04	Non-hazardous	At open site	10	Transfer to waste handling companies
Dredging spoil other than those mentioned in 17 05 05	40	70	Liquid	17 05 06	Non-hazardous	In tanks	5	Transfer to waste handling companies
Track ballast other than those mentioned in 17 05 07	60	80	Solid	17 05 08	Non-hazardous	At open site	10	Transfer to waste handling companies

Waste						Waste storage at site		Proposed methods of waste management
Name	**Total amount for 1 1600/1700 MW power reactor, tonnes**	**Total amount for 2 1600/1700 MW power reactors, tonnes**	**State of aggregation (solid, liquid, paste)**	**Code according to the Waste List**	**Hazardousness**	**Storage conditions**	**Maximum amount, tonnes**	
Other insulation materials consisting of or containing dangerous substances	20	40	Solid	17 06 03*	H14 ecotoxic	In containers	3	Transfer to hazardous waste handling companies
Insulation materials other than those mentioned in 17 06 01 and 17 06 03	140	280	Solid	17 06 04	Non-hazardous	In containers	20	Transfer to waste handling companies
Gypsum-based construction materials other than those mentioned in 17 08 01	40	80	Solid	17 08 02	Non-hazardous	In containers	6	Transfer to waste handling companies
Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	4000	8000	Solid	17 09 04	Non-hazardous	In containers	500	Transfer to waste handling companies
Solid waste from primary filtration and screenings	1	2	Solid	19 09 01	Non-hazardous	In containers	0.3	Transfer to waste handling companies
Paper and cardboard	200	400	Solid	20 01 01	Non-hazardous	In containers	50	Transfer to waste handling companies
Glass	10	20	Solid	20 01 02	Non-hazardous	In containers	2	Transfer to waste handling companies
Fluorescent tubes and other mercury-containing waste	10	20	Solid	20 01 21*	H6 toxic	In containers	1	Transfer to hazardous waste handling companies
Detergents other than those mentioned in 20 01 29	2	4	Liquid	20 01 30	Non-hazardous	In tanks	0.3	Transfer to waste handling companies
Discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	8	16	Solid	20 01 35*	H14 ecotoxic	In containers	0.8	Transfer to hazardous waste handling companies
Discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35	3	5	Solid	20 01 36	Non-hazardous	In containers	0.3	Transfer to waste handling companies
Plastics	2	4	Solid	20 01 39	Non-hazardous	In containers	0.3	Transfer to waste handling companies
Metals	4	8	Solid	20 01 40	Non-hazardous	In containers	2	Transfer to waste handling companies
Biodegradable waste	100	150	Solid	20 02 01	Non-hazardous	In containers	22	Transfer to waste handling

Waste						Waste storage at site		Proposed methods of waste management
Name	**Total amount for 1 1600/1700 MW power reactor, tonnes**	**Total amount for 2 1600/1700 MW power reactors, tonnes**	**State of aggregation (solid, liquid, paste)**	**Code according to the Waste List**	**Hazardousness**	**Storage conditions**	**Maximum amount, tonnes**	
								companies
Soil and stones	20	30	Solid	20 02 02	Non-hazardous	In containers	10	Transfer to waste handling companies
Other non-biodegradable wastes	200	300	Solid	20 02 03	Non-hazardous	In containers	30	Transfer to waste handling companies
Mixed municipal waste	1000	1500	Solid	20 03 01	Non-hazardous	In containers	150	Transfer to waste handling companies
Street-cleaning residues	60	80	Solid	20 03 03	Non-hazardous	In containers	30	Transfer to waste handling companies
TOTAL	**14500**	**27000**	**-**	**-**	**-**	**-**	**2000**	**-**

6.2 OPERATION OF THE NUCLEAR POWER PLANT

6.2.1 Non-radioactive waste

Non-radioactive waste generated during operation of the NPP will be non-hazardous waste (package of various equipment, cables, metal, plastic, discarded equipment, insulation materials, protective clothes, mixed municipal waste, etc.) and ecotoxic or toxic waste (discarded equipment containing hazardous components; waste paint, varnish, adhesives and sealants containing organic solvents or other dangerous substances; aqueous and oil emulsion containing turbine, transformer and other oils; batteries and accumulators; fluorescent tubes and other mercury-containing waste, absorbents, filter materials, wiping cloths, contaminated by petroleum products, etc.). According to a preliminary estimation during the operation and maintenance stage for one 1600/1700 MW power reactor approximately 500 tones (including about 160 tonnes, i.e. about 32 % of hazardous waste), and for two 1600/1700 MW power reactors approximately 900 tones (including about 320 tonnes, i.e. about 35 % of hazardous waste) of non-radioactive waste will be produced. All the waste will be managed according to the requirements of the Law on Waste Management (*State Journal, 2002, No. 72-3016*), the Rules of Waste Management (*State Journal, 2004, No. 68-2381; 2007, No. 11-461*), as well as of the Permission on Integrated Pollution Prevention and Control. Potential amounts of waste, produced during the operation and maintenance of the new NPP, technological processes, which will produce the waste, waste aggregative state, code pursuant to the Waste List, hazardousness, conditions of waste storage at a site and proposed waste management methods are given in Table 6.2–1.

Table 6.2–1. Waste and waste management during the operation stage of the NNPP.

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During cleaning of water filters	Waste sand and clays (quartz sand)	0.5	1	Solid	01 04 09	Non-hazardous	In containers	0.5	Transfer to waste handling companies
During repair works	Waste paint and varnish containing organic solvents or other dangerous substances	0.1	0.2	Liquid	08 01 11*	H14 ecotoxic	In containers	0.05	Transfer to hazardous waste handling companies
During repair works	Waste paint and varnish other than those mentioned in 08 01 11	0.4	0.8	Liquid	08 01 12	Non-hazardous	In tanks	0.4	Transfer to waste handling companies
During repair works	Wastes from paint or varnish removal containing organic solvents or other dangerous substances	1	2	Liquid	08 01 17*	H14 ecotoxic	In tanks	0.5	Transfer to hazardous waste handling companies
During repair works	Wastes from paint or varnish removal other than those mentioned in 08 01 17	0.1	0.2	Liquid	08 01 18	Non-hazardous	In tanks	0.1	Transfer to waste handling companies
During repair works	Waste paint or varnish remover	0.1	0.2	Liquid	08 01 21*	H14 ecotoxic	In tanks	0.05	Transfer to hazardous waste handling companies
During repair works	Waste adhesives and sealants containing organic solvents or other dangerous substances	0.2	0.4	Paste	08 04 09*	H14 ecotoxic	In containers	0.1	Transfer to hazardous waste handling companies
During repair works	Waste adhesives and sealants other than those mentioned in 08 04 09	10	20	Paste	08 04 10	Non-hazardous	In containers	10	Transfer to waste handling companies
During operation	Sealant of hot water tanks, containing dangerous substances	5	10	Paste	08 04 99*	H14 ecotoxic	In containers	2.5	Transfer to hazardous waste handling companies
During metal processing	Ferrous metal filings and turnings	10	20	Solid	12 01 01	Non-hazardous	In containers	5	Transfer to waste handling companies
During metal processing	Non-ferrous metal filings and turnings	1	2	Solid	12 01 03	Non-hazardous	In containers	0.5	Transfer to waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During plastic processing	Plastics shavings and turnings	0.1	0.2	Solid	12 01 05	Non-hazardous	In containers	0.1	Transfer to waste handling companies
During operation and repair works of machines	Mineral-based machining oils free of halogens (except emulsions and solutions)	2	4	Liquid	12 01 07*	H14 ecotoxic	In tanks	1	Transfer to hazardous waste handling companies
During operation and repair works of equipment	Synthetic machining oils	1	2	Liquid	12 01 10*	H14 ecotoxic	In tanks	0.5	Transfer to hazardous waste handling companies
During metal processing	Welding wastes	1	2	Solid	12 01 13	Non-hazardous	In containers	1	Transfer to waste handling companies
During operation and repair works	Other engine, gear and lubricating oils	1	2	Liquid	13 02 08*	H14 ecotoxic	In tanks	0.5	Transfer to hazardous waste handling companies
During operation and repair works	Other insulating and heat transmission oils	30	60	Liquid	13 03 10*	H14 ecotoxic	In tanks	15	Transfer to hazardous waste handling companies
During cleaning of surface water purification plant	Sludges from oil/water separators	1	2	Liquid	13 05 02*	H14 ecotoxic	In tanks	0.5	Transfer to hazardous waste handling companies
During cleaning of surface water purification plant	Oily water from oil/water separators	2	4	Liquid	13 05 07*	H14 ecotoxic	In tanks	1	Transfer to hazardous waste handling companies
During operation and repair works	Other emulsions (aqueous and oil emulsion containing turbine, transformer and other oils)	50	100	Liquid	13 08 02*	H14 ecotoxic	In tanks	25	Transfer to hazardous waste handling companies
During building repair works	Other halogenated solvents and solvent mixtures	0.1	0.2	Liquid	14 06 02*	H14 ecotoxic	In tanks	0.05	Transfer to hazardous waste handling companies
During building repair works	Other solvents and solvent mixtures	0.1	0.2	Liquid	14 06 03*	H14 ecotoxic	In tanks	0.05	Transfer to hazardous waste handling companies
During operation and repair works (equipment package)	Paper and cardboard packaging	3	6	Solid	15 01 01	Non-hazardous	In containers	1.5	Transfer to waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During operation and repair works (equipment package)	Plastic packaging	5	10	Solid	15 01 02	Non-hazardous	In containers	2.5	Transfer to waste handling companies
During operation and repair works (equipment package)	Wooden packaging	5	10	Solid	15 01 03	Non-hazardous	In containers	2.5	Transfer to waste handling companies
During operation and repair works (equipment package)	Metallic packaging	8	16	Solid	15 01 04	Non-hazardous	In containers	4	Transfer to waste handling companies
During operation and repair works (equipment package)	Composite packaging	7	14	Solid	15 01 05	Non-hazardous	In containers	3.5	Transfer to waste handling companies
During operation and repair works (equipment package)	Mixed packaging	20	40	Solid	15 01 06	Non-hazardous	In containers	10	Transfer to waste handling companies
During operation and repair works (foodstuff package at canteen)	Glass packaging	1	2	Solid	15 01 07	Non-hazardous	In containers	0.5	Transfer to waste handling companies
During operation, in case of spillage of petroleum products	Absorbents, filter materials, wiping cloths, contaminated by dangerous substances (petroleum products)	1	2	Solid/ Liquid	15 02 02*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
During operation , in case of spillage of petroleum products	Absorbents (sawdust, sand contaminated by petroleum products)	5	10	Solid/ Liquid	15 02 02*	H14 ecotoxic	In containers	2.5	Transfer to hazardous waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During operation and repair works	Absorbents, filter materials, wiping cloths and protective clothing other than those mentioned in 15 02 02	20	40	Solid	15 02 03	Non-hazardous	In containers	10	Transfer to waste handling companies
During repair works of forklifts	End-of-life tyres	3	6	Solid	16 01 03	Non-hazardous	In garage	1.5	Transfer to waste handling companies
During operation and repair works, when discarding disused equipment	Discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12	10	15	Solid	16 02 13*	H14 ecotoxic	In warehouse	2.5	Transfer to hazardous waste handling companies
During repair works of equipment, when discarding disused equipment	Discarded equipment other than those mentioned in 16 02 09 to 16 02 13 (details and components of equipment, insulators of glass and porcelain)	20	30	Solid	16 02 14	Non-hazardous	In containers	10	Transfer to waste handling companies
During repair works of equipment, when discarding disused equipment	Components removed from discarded equipment other than those mentioned in 16 02 15	20	30	Solid	16 02 16	Non-hazardous	In containers	5	Transfer to waste handling companies
After expire date of NNPP laboratory reagents	Discarded inorganic chemicals consisting of or containing dangerous substances	3	5	Solid/ Liquid	16 05 07*	H14 ecotoxic	In containers	1.5	Transfer to hazardous waste handling companies
After expire date of NNPP laboratory reagents	Discarded organic chemicals consisting of or containing dangerous substances	2	3	Solid/ Liquid	16 05 08*	H14 ecotoxic	In containers	1	Transfer to hazardous waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
When changing fire extinguisher powder	Discarded chemicals other than those mentioned in 16 05 06, 16 05 07 or 16 05 08	0.4	0.8	Solid	16 05 09	Non-hazardous	In containers	0.4	Transfer to waste handling companies
When changing batteries of electrical workshop	Lead batteries	3	6	Solid	16 06 01*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
During repair works of vehicles	Alkaline batteries (except 16 06 03)	5	9	Solid	16 06 04	Non-hazardous	In containers	1.5	Transfer to waste handling companies
During operation and repair works	Other batteries and accumulators	1	1.5	Solid	16 06 05	Non-hazardous	In containers	0.5	Transfer to waste handling companies
During repair works of equipment	Separately collected electrolyte from batteries and accumulators (acid electrolyte)	10	15	Liquid	16 06 06*	H14 ecotoxic	In tanks	2.5	Transfer to hazardous waste handling companies
During repair works of equipment	Separately collected electrolyte from batteries and accumulators (alkaline electrolyte)	1	1.5	Liquid	16 06 06*	H14 ecotoxic	In tanks	0.3	Transfer to hazardous waste handling companies
During construction and repair works	Wastes containing oil (waste from cleaning tanks for petroleum products)	25	50	Liquid	16 07 08*	H14 ecotoxic	In tanks	5	Transfer to hazardous waste handling companies
During construction and repair works	Concrete	40	60	Solid	17 01 01	Non-hazardous	In containers	1	Transfer to waste handling companies
During construction and repair works	Bricks	2	3	Solid	17 01 02	Non-hazardous	In containers	1	Transfer to waste handling companies
During construction and repair works	Tiles and ceramics	0.5	1	Solid	17 01 03	Non-hazardous	In containers	0.3	Transfer to waste handling companies
During construction and repair works	Wood (timber, sleepers)	20	30	Solid	17 02 01	Non-hazardous	In containers	5	Transfer to waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During construction and repair works	Plastic	2	3	Solid	17 02 03	Non-hazardous	In containers	1	Transfer to waste handling companies
During construction and repair works	Bituminous mixtures other than those mentioned in 17 03 01	0.5	1	Solid/ Paste	17 03 02	Non-hazardous	In containers	0.3	Transfer to waste handling companies
During construction and repair works	Coal tar and tarred products	10	20	Solid/ Paste	17 03 03*	H14 ecotoxic	In containers	2.5	Transfer to hazardous waste handling companies
During construction and repair works	Copper, bronze, brass	0.2	0.4	Solid	17 04 01	Non-hazardous	In containers	0.1	Transfer to waste handling companies
During construction and repair works	Aluminium	2	4	Solid	17 04 02	Non-hazardous	In containers	1	Transfer to waste handling companies
During construction and repair works	Lead	1	2	Solid	17 04 03	Non-hazardous	In containers	0.5	Transfer to waste handling companies
During construction and repair works	Iron and steel	5	10	Solid	17 04 05	Non-hazardous	In containers	1.5	Transfer to waste handling companies
During construction and repair works	Mixed metals	10	20	Solid	17 04 07	Non-hazardous	In containers	3	Transfer to waste handling companies
During construction and repair works	Cables other than those mentioned in 17 04 10	1	2	Solid	17 04 11	Non-hazardous	In containers	1	Transfer to waste handling companies
During territory keeping and cleaning	Soil and stones containing dangerous substances	1	2	Solid	17 05 03*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During territory keeping and cleaning	Soil and stones other than those mentioned in 17 05 03	2	3	Solid	17 05 04	Non-hazardous	In containers	1	Transfer to waste handling companies
During construction and repair works	Other insulation materials consisting of or containing dangerous substances	1	2	Solid	17 06 03*	H14 ecotoxic	In containers	0.5	Transfer to hazardous waste handling companies
During operation and repair works	Insulation materials other than those mentioned in 17 06 01 and 17 06 03	5	10	Solid	17 06 04	Non-hazardous	In containers	2.5	Transfer to waste handling companies
During operation and repair works	Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	10	20	Solid	17 09 04	Non-hazardous	In containers	5	Transfer to waste handling companies
During operation of pump-house	Solid waste from primary filtration and screenings	1.5	3	Solid	19 09 01	Non-hazardous	In containers	1	Transfer to waste handling companies
During repair works of water filters	Spent activated carbon	5	10	Paste	19 09 04	Non-hazardous	In containers	3	Transfer to waste handling companies
During repair works of water filters	Saturated or spent ion exchange resins	5	10	Paste	19 09 05	Non-hazardous	In containers	3	Transfer to waste handling companies
During Office work and discarding of unnecessary literature	Paper and cardboard	5	8	Solid	20 01 01	Non-hazardous	In containers	2.5	Transfer to waste handling companies
During operation and repair works	Glass	1	1.5	Solid	20 01 02	Non-hazardous	In containers	0.5	Transfer to waste handling companies
In case of burn-out of lighting equipment	Fluorescent tubes and other mercury-containing waste	2	4	Solid	20 01 21*	H6 toxic	In containers	0.5	Transfer to hazardous waste handling companies

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Amount for 1 1600/1700 MW power reactor, t/year	Amount for 2 1600/1700 MW power reactors, t/year	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness	Storage conditions	Maximum amount, tonnes	
During equipment cleaning	Detergents other than those mentioned in 20 01 29	0.5	1	Liquid	20 01 30	Non-hazardous	In tanks	0.3	Transfer to waste handling companies
When discarding unnecessary equipment	Discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	0.1	0.2	Solid	20 01 35*	H14 ecotoxic	In containers	0.05	Transfer to hazardous waste handling companies
In case of failure of lighting or other equipment	Discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35	0.1	0.2	Solid	20 01 36	Non-hazardous	In containers	0.1	Transfer to waste handling companies
In course of economic activity	Plastics	0.5	0.8	Solid	20 01 39	Non-hazardous	In containers	0.25	Transfer to waste handling companies
During operation and repair works	Metals	1	1.7	Solid	20 01 40	Non-hazardous	In containers	0.5	Transfer to waste handling companies
When tidying NNPP territory	Biodegradable waste	10	15	Solid	20 02 01	Non-hazardous	In containers	2.5	Transfer to waste handling companies
In course of economic activity	Mixed municipal waste	50	80	Solid	20 03 01	Non-hazardous	In containers	20	Transfer to waste handling companies
When cleaning NNPP territory	Street-cleaning residues	10	15	Solid	20 03 03	Non-hazardous	In containers	4	Transfer to waste handling companies
TOTAL		**500**	**900**	-	-	-	-	**200**	-

6.2.2 Radioactive waste

Radioactive waste originating from nuclear power plants usually includes spent nuclear fuel, operating waste and the so-called decommissioning waste originating from the decommissioning of the plant.

The main principles of radioactive waste management are established by Clause 3 of the Law on Radioactive Waste Management (*State Journal, 1999, No. 50-1600; 2005, No 122-4361*). Management of radioactive waste must ensure that:

- At all stages of the radioactive waste management, by applying appropriate methods, individuals, society and the environment in Lithuania and beyond its borders are adequately protected against radiological, biological, chemical and other hazards that may be associated with radioactive waste;
- The generation of radioactive waste is kept to the minimum practicable;
- Interdependencies among the different steps in the radioactive waste management are taken into account;
- Safety of radioactive waste management facilities is guaranteed during their operating lifetime and after it.

VATESI document "Regulation on the Pre-Disposal Management of Radioactive Waste at the Nuclear Power Plant, VD-RA-01-2001" (*State Journal, 2001, No. 67-2467*) is applied to the safety of the pre-disposal management of radioactive waste generated from the operation and decommissioning of NPP and other radioactive waste that is transferred to NPP for storage and/or processing. This regulation sets the procedure of management both the waste from past activities and newly generated waste, except spent nuclear fuel.

A radioactive waste management program must be implemented at the new NPP independent of what reactor type and design will be chosen. This program will include the following:

- keeping the generation of radioactive waste to the practicable minimum, in terms of both activity and volume, by using suitable technology;
- reusing and recycling materials to the extent possible;
- classifying and segregating waste appropriately, and maintaining an accurate inventory for each radioactive waste stream, with account taken on the available options for clearance and disposal;
- collecting, characterizing and storing radioactive waste so that it is acceptably safe;
- providing adequate storage capacity for anticipated radioactive waste;
- ensuring that radioactive waste can be retrieved in the end of the storage period;
- treating and conditioning radioactive waste in a way that is consistent with safe storage and disposal;
- handling and transporting radioactive waste safely;
- controlling effluent discharges to the environment;
- carrying out monitoring for compliance at source and in the environment;
- maintaining facilities and equipment for waste collection, processing and storage in order to ensure safe and reliable operation;
- monitoring the status of the containment for the radioactive waste in the storage location;
- monitoring changes in the characteristics of the radioactive waste, in particular if storage is continued for extended periods, by means of inspection and regular analysis;

- initiating, as necessary, research and development to improve existing methods for processing radioactive waste or to develop new methods, and to ensure that suitable methods are available for the retrieval of stored radioactive waste.

Most of the waste produced during normal operation of a NPP is very low and low in radioactivity. This waste mostly includes typical maintenance waste, such as isolation materials, paper, old working clothes, machine parts, plastics and oil. The intermediate-level waste mainly consists of the ion exchange resin from the purification system of the circulating water and the evaporator bottom from sewage water treatment.

Radioactive waste is classified and segregated in accordance with the physical state (solid, liquid or gaseous), chemical properties (aqueous waste or organic liquids) and radiological properties (very low, low or intermediate level waste, short-lived or long-lived waste). The segregation of the radioactive waste is carried out taking into consideration their flammable, pyrophoric, explosive and corrosive nature.

The amounts of solid, liquid and gaseous operating wastes and spent nuclear fuel are evaluated in this section based on the reactor types which are selected as technological alternatives (see Chapters 4 and 5). Also possible radioactive waste management, treatment, storage and disposal methods are described. The radionuclide releases to the environment from the new NPP and their impact assessments given in Chapter 7 also consider the possible releases from the radioactive waste and spent nuclear fuel storage facilities of the new NPP.

6.2.2.1 Solid radioactive waste

Solid radioactive waste consists of cartridge filters; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; contaminated rags, clothing, paper, plastic, etc.; and spent ion exchange resins (according to IAEA classification, spent ion exchange resins are wet solid waste). Annual solid waste generation rates for different reactor types, which are considered as technological alternatives, are summarized in Table 6.2–2. The amount of radioactive waste produced depends on the reactor type and model, as well as on the planned number of units. To compare the quantity of solid radioactive waste produced in different reactors, the annual waste quantity is normalized to one GW of power plant capacity. The comparison of the annual waste quantities per one GW (see Table 6.2–2) shows that the relative maximum amount of solid radioactive waste is produced in BWR-type reactors. The volume of waste produced by PWR-type reactors is 1.5–2 times, and by PHWR-type reactors – about 6 times smaller than the volume produced by BWR-type reactors. It should be mentioned that among the different models of PWR-type reactors annual waste volume per one GW is also different. These differences relate to the peculiarities of the radioactive waste management program, introduced in these reactor models. In case of any reactor model the volume of solid radioactive waste per one GW is lower than that of the existing Ignalina NPP – here one GW corresponds to ~ 420 m^3 per year.

Table 6.2–2. Annual generation of solid radioactive waste.

Reactor type	Reactor model	For one Unit, m^3/year	Planned number of Units and their total electrical power	Total amount from all Units, m^3/year	Annual amount per one GW
BWR	**ABWR (*DCD ABWR, 2007*)**	~430	2 / 2600 MW	~860	~330
	ESBWR (*DCD ESBWR, 2007*)	~470	2 / 3100 MW	~940	~300
PWR	**EPR (*EPR FSAR, 2007*)**	~225	2 / 3320 MW	~450	~135
	APWR (*DCD APWR, 2007*)	~310	2 / 3400 MW	~620	~180
	AP-1000 (*DCD AP-1000, 2005*)	~160	3 / 3300 MW	~480	~145
	AP-600 (*DCD AP-600, 1999*)	~140	5 / 3000 MW	~600	~200
	WWER (*IAEA-TECDOC-1492*)	120-250	V-392 (3 Units/3018 MW) V-448 (2 Units/3000 MW)	240-750	85-250
HWR	**CANDU-6 (*TQ AECL, 2008*)**	~40	4 / 3000 MW	~160	~50
	ACR-1000 (*EIA ACR-1000, 2006*)	~55	3 / 3255 MW	~165	~50

It shall be noted that in Table 6.2–2 the amounts presented are for untreated waste. Before the treatment solid waste shall be classified and segregated in accordance with the radiological classification parameters given in Table 6.2–3.

Table 6.2–3. Solid radioactive waste classification system (extracted from VD-RA-01-2001 (*State Journal, 2001, No. 67-2467*).

Waste class	Definition (abbreviation)	Surface dose rate, mSv/h	Conditioning option	Disposal method
0	Exempt waste (EW)		Not required	Management and disposal as per requirements set in Law on Waste Management (*State Journal, 1998. No. 61-1726; 2002, No. 72-3016*)
Short-Lived low and intermediate level waste*)				
A	Very low level waste (VLLW)	≤0.5	Not required	Very low level waste repository (Landfill repository)
B	Low level waste (LLW-SL)	0.5–2	Required	Near surface repository
C	Intermediate level waste (ILW-SL)	>2	Required	Near surface repository
Long-Lived low and intermediate level waste**)				
D	Low level waste (LLW-LL)	≤10	Required	Near surface repository (cavities at intermediate depth)

Waste class	Definition (abbreviation)	Surface dose rate, mSv/h	Conditioning option	Disposal method
E	Intermediate level waste (ILW-LL)	>10	Required	Deep geological repository
Spent sealed sources				
F	Spent sealed sources (SSS)		Required	Near surface or deep geological repository***)

*) Containing beta and/or gamma emitting radionuclides with half-lives less than 30 years, including Cs-137, and/or long-lived alpha emitting radionuclides with measured and/or calculated, by using approved methods, activity concentration less than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long-lived alpha emitting radionuclides is less than 400 Bq/g per waste package.
**) Containing beta and/or gamma emitting radionuclides with half-lives more than 30 years, not including Cs-137, and/or long-lived alpha emitting radionuclides with measured and/or calculated, by using approved methods, activity concentration more than 4000 Bq/g in individual waste packages on condition that an overall average activity concentration of long-lived alpha emitting radionuclides exceeds 400 Bq/g per waste package.
***) Depending on acceptance criteria applied to sealed sources.

Very low level radioactive waste does not require conditioning. Waste should be solid, not containing free liquids. They are disposed of at very low level radioactive waste repositories (Landfill repositories). Waste packages must be properly wrapped in plastic or otherwise packaged. Surface contamination and resulting dose rate of packaged waste and individual pieces of waste should not exceed the set acceptable limits of the waste acceptance criteria for disposal at Landfill repository.

There are a lot of well established and worldwide used technologies for treatment of solid radioactive waste. Treatments for solid radioactive waste are used to reduce the volume of the waste and/or convert the waste into a form suitable for handling, storage and disposal. The main treatment methods are following:

- Decontamination – appropriate removal of the contamination from the surface could consequently convert equipment or material that had to be considered as radioactive waste into conventional waste or material that can be reused;
- Compaction – is a widely used method to reduce the volume of dry compactable radioactive solid waste through the application of a mechanical force. Depending on solid radioactive waste characteristics the waste volume can be reduced 3 to 8 times by compaction;
- Incineration – produces a high volume reduction and converts the combustible radioactive waste into a form suitable for subsequent immobilization and disposal. Using this treatment technology the mass of combustible solid radioactive waste can be reduced up to 10 times, and the volume from 30 to 100 times.

Non-combustible and non-compactable radioactive waste often requires special treatment, depending on its particular characteristics. Those wastes contaminated with long lived radioisotopes, such as sealed sources, should be immobilized prior to their storage and disposal. Traditionally, cement grouts have been used or recommended as the most suitable material for conditioning radioactive non-compactable waste.

Solid radioactive waste of the new NPP will be managed, stored and disposed of in accordance with the Radioactive Waste Management Strategy, approved by the resolution No. 860 of the Government of the Republic of Lithuania of September 3, 2008 (*State Journal, 2008, No. 105-4019*). The State Long-term Development Strategy, approved by the resolution No. IX-1187 of the Lithuanian Parliament of November 12, 2002 (*State Journal, 2002, No. 113-5029*), the National Energy Strategy, approved by the resolution No. X-1046 of the Lithuanian Parliament of January 18, 2007 (*State*

Journal, 2007, No. 11-430), and the European Union's energy policy has allowed to determine the appropriate objectives for the radioactive waste management strategy, the priorities and the measures needed to implement them. The radioactive waste management strategy provides the main radioactive waste management policies, in view of the nuclear energy development plans, the latest national and international environment, nuclear and radiation safety requirements, the Joint Convention on the Safety of Spent Nuclear Fuel Management and Safety of Radioactive Waste Management (*State Journal, 2004, No. 36-1186*). This strategy provides objectives and tasks for the radioactive waste management, including those intended to prepare for using the latest technologies during the new NPP operational radioactive waste management.

At the new NPP solid radioactive waste will be handled at the new NPP solid waste management facilities, the treated waste will be stored at the NNPP, and later disposed of. The projects of a very low level radioactive waste repository and a low and intermediate level short-lived radioactive waste near-surface repository, being currently implemented at INPP, are intended only for disposal of Ignalina NPP operational and decommissioning radioactive waste, therefore new repositories will have to be designed and constructed for the new NPP radioactive waste. Opportunities to expand a near-surface repository foreseen to be constructed on Stabatiskes site near the INPP, allowing to adapt a part of the vaults for disposal of the NNPP radioactive waste, are low due to the lack of area for installation of additional vaults on the site. The envisaged alternative sites for INPP very low level waste repository have enough area to accommodate separate modules for the new NPP waste, as well. 5 years later the Radioactive Waste Management Strategy will need to be updated and approved by a resolution of the Government; it should also include the further NNPP radioactive waste management strategy.

As the experience of the currently ongoing INPP projects show, radiological impact of the solid waste treatment and storage facility (SWTSF) and the new repositories on the population and the environment is negligible. E.g., an annual effective dose to a member of the critical group of the population at the location of the highest exposure (INPP SPZ) due to radioactive releases from the SWTSF is as follows: to children - about 0.003 mSv, to adults – 0.001 mSv (*EIA Report for New Solid Waste Management and Storage Facility at Ignalina NPP, 2008*).

According to the fourth result criterion of the 2nd objective of the Radioactive Waste Management Strategy (*State Journal, 2008, No. 105-4019*), the present value (2008) of treated low and intermediate level solid radioactive waste constitutes 0 per cent, the target value (2030) is 90 percent. The Government of the Republic of Lithuania endorsed the designing of INPP radioactive waste near-surface repository by the resolution No. 1227 of November 21, 2007 “On the designing of a near-surface repository for low and intermediate level short-lived radioactive waste” (*State Journal, 2007, No. 122-5006*).

Long-lived intermediate level solid radioactive waste will be stored at the new NPP; however, they will not be conditioned, since pursuant to the eighth task of the 2 objective of the Radioactive Waste Management Strategy (*State Journal, 2008, No. 105-4019*) possibilities of disposal, export for reprocessing or disposal of spent nuclear fuel and long-lived radioactive waste in other countries should be analyzed. In accordance with Clause 9 of this Strategy, in 2002–2006 during the implementation of the Program of Assessment of Spent Nuclear Fuel and Long-lived Radioactive Waste Disposal Possibilities for 2003–2007, approved by the Order No. 53 of the Director of the state enterprise Radioactive Waste Management Agency of October 15, 2003, there were analyzed possibilities to arrange a deep geological repository in Lithuania, a regional deep geological repository of several European Union member states and to transfer spent nuclear fuel to the states that own proper installations and assume responsibility for the this waste. If the global policy on spent nuclear fuel and radioactive waste transfer to other states is not changed or new spent nuclear fuel reprocessing technologies do not occur, not earlier than in 2030 it will be started to consider, what location of Lithuania shall be used for construction of a deep geological repository for radioactive waste.

6.2.2.2 Liquid radioactive waste

The primary coolant in water cooled reactors and water from the spent nuclear fuel storage pools are major potential sources of liquid radioactive waste since some of their radioactive content may be transported to the liquid radioactive waste stream via process streams or leakages. Another source of liquid radioactive waste is liquids generated in controlled access area:

- sewage water from showers and toilets;
- waste water from cleaning and decontamination of equipment and building structures,
- condensation water from building structures and constructions surfaces;
- condensation water from heating, ventilation and air conditioning system;
- leakages and drainages from reactor systems.

Annual liquid radioactive waste generation rates for different reactor types which are considered as technological alternatives are summarized in Table 6.2–4. As in the case of solid radioactive waste, in order to compare the volumes of liquid radioactive waste produced in different types and models of reactors, the annual waste volume is normalized to one GW of a power plant capacity. Comparison of the annual quantity of waste per one GW (see Table 6.2–4) shows that the relative maximum volume of liquid radioactive waste is produced in BWR and PHWR-type reactors, and PWR type reactors produce about 5 times smaller amount of liquid radioactive waste. The model of WWER reactor forms an exception, since the data on the volume of liquid radioactive waste is based on the operating experience of Soviet/Russian WWER reactors, where, like in the RBMK reactors, the principles of attribution of liquid materials to radioactive waste are different from those applied for the Western reactors.

Table 6.2–4. Annual generation of liquid radioactive waste.

Reactor type	Reactor model	For one Unit, m^3/year	Planned number of Units and their total electrical power	Total amount from all Units, m^3/year	Annual amount per one GW
BWR	ABWR (*DCD ABWR, 2007*)	~29500	2 / 2600 MW	~59000	~22700
	ESBWR (*DCD ESBWR, 2007*)	~28600	2 / 3100 MW	~57200	~18500
PWR	EPR (*EPR FSAR, 2007*)	~8000	2 / 3320 MW	~16000	~4800
	APWR (*DCD APWR, 2007*)	~7000	2 / 3400 MW	~14000	~4100
	AP-1000 (*DCD AP-1000, 2005*)	~2500	3 / 3300 MW	~7500	~2300

	AP-600 (*DCD AP-600, 1999*)	~2300	5 / 3000 MW	~11500	~3800
	WWER (*IAEA-TECDOC-1492*)	~15000	V-392 (3 Units/3018 MW) V-448 (2 Units/3000 MW)	30000–45000	10000–15000
HWR	**CANDU-6 (*TQ AECL, 2008*)**	~14000	4 / 3000 MW	~56000	~19000
	ACR-1000 (*EIA ACR-1000, 2006*)	n/a	3 / 3255 MW	n/a	n/a

It shall be noted that in Table 6.2–4 the presented amounts are for untreated waste. Before the treatment liquid radioactive waste shall be classified and segregated according to:

- The specific activity: in low level ($\leq 4 \cdot 10^5$ Bq/l) and intermediate level ($>4 \cdot 10^5$ Bq/l) waste;
- The chemical nature: in aqueous and organic waste;
- The phase state: in homogeneous and heterogeneous waste.

Liquid waste shall be further classified according to its chemical composition and shall be led to appropriate liquid radioactive waste treatment facilities. The suitability of existing treatment facilities and plants and the necessity of the new treatment facilities are evaluated in Section 1.8.

Methods for the treatment of liquid radioactive waste include evaporation, membrane processing (e.g. reverse osmosis, ultrafiltration, non-precoat filters), electro deionization, ion exchange, chemical precipitation, filtration, centrifugation, electro-dialysis and incineration. A particularly efficient treatment method is evaporation. During evaporation the volume of liquid radioactive waste can be reduced from 100 to 400 times. Using the ion exchange treatment methods the waste volume can be reduced from 10 to 100 times, and in case of chemical precipitation from 20 to 50 times.

In each case, treatment limitations should be included in the categorization process. For example, strong consideration shall be put on the impact of corrosion, scaling, foaming, and the risk of fire or explosion in the presence of organic material, especially with regard to the safety implications of operations and maintenance.

All process and household waste water, produced within the controlled area of the new NPP, will be treated as potentially radioactive waste. All waste water, including household waste water from showers and wash basins, will be collected in tanks, equipped with sampling systems; chemical and radiological parameters of the accumulated waste water will be measured. After the assessment of the measurement results, the collected waste water will be transferred into the new NPP liquid radioactive waste treatment facilities or discharged into the household–process waste water system. Waste water from the collection tanks will be discharged into the household–process waste water system only according to the procedure, set out by the Lithuanian legal acts, after the permission to release radionuclides into the environment has been obtained, provided that the values of activity limits indicated in the permit are not exceeded. Specific procedures for liquid waste removal from the collection tanks (including the assessment of waste water measurement results), as well as values of activity limits will be developed in accordance with the provisions of normative documents in force, before the commissioning of the new NPP.

Radioactive materials may be released into environment only after the permission for discharges of radioactive substances to the environment is obtained. This permission is issued by the Lithuanian Ministry of Environment to the operator of the nuclear installation according to the conditions and procedures established in regulations and following the requirements of the normative document LAND 42-2007 “On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring” (*State Journal, 2007, No. 138-5693*). Possible radioactive effluents into the environment from different reactor types during normal operation are described in Section 7.1.2.

Liquid radioactive waste of the new NPP will be treated in the NNPP liquid radioactive waste treatment facilities. At Ignalina NPP the Cement Solidification Facility for liquid radioactive waste solidification has been commissioned, the possibility (after completion of solidification of all foreseen INPP liquid radioactive waste) of later utilization of this Cement Solidification Facility and the Interim Storage Facility for the new NPP liquid radioactive waste solidification and storage also will be considered during the designing of the new NPP. According to the second performance criterion of the 2nd objective of the Radioactive Waste Management Strategy (*State Journal, 2008, No. 105-4019*), the present value (2008) of treated liquid radioactive waste constitutes 17 per cent, the target value (2030) is 90 percent.

6.2.2.3 Gaseous radioactive waste

Although the sources of gaseous radioactive waste depend on the reactor type, the main sources of generation of such waste are as follows:

- The leakage from the cooling circuit, the moderator system or the reactor itself;
- The degassing systems of the cooling circuit;
- Vacuum air ejectors or pumps of the condenser;
- Activated or contaminated air in the ventilation systems;
- Spent nuclear fuel processing or storage in the pools.

In order to minimize the volume of gaseous radioactive waste and to limit their generation, the following technical and administrative measures are applied:

- The reactor is operated so as to produce as small number of damaged fuel assemblies as possible;
- The time of stay of the damaged fuel assembly in the reactor is optimized;
- It is aimed to ensure that the reactor coolant includes minimum of impurities;
- Filtration of gaseous radioactive waste is carried out (by separation of aerosols or iodine in the gas stream);
- Specific systems retaining gaseous radioactive waste are used where fission of radionuclides present in the gases occurs;
- Measures of reduction of gaseous radioactive waste volume are employed.

Systems for gaseous radioactive waste processing present at nuclear power plants are designed taking into account the volume of gas processed, the radionuclide inventory and radionuclide activity in the gas, aerosol concentration, as well as the chemical composition, moisture, toxicity, corrosive and explosive properties of the gas. Both at normal NPP operating conditions and in case of anticipated operational occurrences, the gaseous radioactive waste treatment systems shall retain aerosols, inert radioactive gas, and iodine in the gaseous radioactive waste to such a degree, that the airborne releases meet the requirements of the normative document LAND 42-2007 "On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring" (*State Journal, 2007, No. 138-5693*). Filters and sorbents used by the gaseous radioactive waste processing system are classified and handled as solid radioactive waste.

6.2.2.4 Spent nuclear fuel

After SNF is removed from the reactor core, it is stored in storage pools for a certain period before SNF could be transferred to off-site facilities for further processing or storage. All NPPs have such spent fuel pools associated with the reactor operations. Recent designs of reactors have incorporated pools that can accommodate SNF generated over periods of up to 30 years. Long-term storage and disposal of SNF will be a subject of an own EIA procedure in the future and this issue is not a subject of this EIA Report.

Annual SNF generation rate of different reactor types which are considered as technological alternatives are summarized in the Table 6.2–5. Annual generation for one reactor was calculated taking into account thermal power of the reactor, average fuel burnup and reactor availability per year. To compare the quantity of SNF produced in different reactors, the annual SNF quantity is normalized to one GW of a power plant capacity (see the last column of Table 6.2–5). As it can be seen, the annual amount of SNF per one GW produced by the models of BWR and PWR type reactor does not differ significantly. However, in case of PHWR reactors, the amount of SNF produced for the model EC-6 is about 7 times, and for the model ACR-1000 – about 2–3 times higher than for BWR and PWR-type reactors. This increased amount of SNF is due to the fact that PHWR uses either natural fuel (EC-6) or low-enriched nuclear fuel (ACR-1000). However, although the PHWR reactors produce a greater amount of SNF, the activities of SNF degradation products for this type of reactors are lower (see Table 6.2–6), and this influences the choice of technology for SNF storage and the design of biological protection of storage facilities. When comparing the amounts of generated SNF in the existing Ignalina nuclear power plant, during the operation of one Ignalina NPP unit, 50–70 tons of SNF are produced per year (annual amount per one GW is 38–54 tonnes). This alternation range of SNF amount is due to the fact that at the existing Ignalina NPP nuclear fuel with different initial enrichment (from 2.0 % to 2.8 %) is used.

Table 6.2–5. Annual generation of SNF.

Reactor type	Reactor model	For one Unit, tonnes/year	Planned number of Units and their total electrical power	Total from all Units, tonnes/year	Annual amount per one GW
BWR	ABWR	26.4	2 / 2600 MW	52.8	~20
	ESBWR	30.2	2 / 3100 MW	60.4	~20
PWR	EPR	23.4	2 / 3320 MW	46.8	~15
	APWR	27.4	2 / 3400 MW	54.8	~16
	AP-1000	17.6	3 / 3300 MW	52.8	~16
	AP-600	10.0	5 / 3000 MW	50.0	~17
	WWER (V-392)	21.4	3 / 3018 MW	64.2	~21
	WWER (V-448)	27.3	2 / 3000 MW	54.6	~20

HWR	**EC-6**	92.4	4 / 3000 MW	369.6	~132
	ACR-1000	53.5	3 / 3255 MW	160.5	~49

There are different SNF management options. The selection of a strategy for SNF management is a complex decision with many factors to be taken into account including politics, economics, resource conservation, environmental protection, and public perception. Main strategies for SNF management are as follows:

- Storage of SNF in pool type facilities away from the reactor. Such facilities where SNF is submerged under the water are usually referred to as SNF wet storage facilities.
- The dry storage technology is used for SNF storage away from the reactor. Such SNF management is presently chosen for Ignalina NPP spent fuel storage.
- SNF reprocessing. During this process useful elements such as uranium and plutonium are separated from fission products and other materials in SNF. Reprocessing facilities exist in UK, France and Russia.

SNF management options and technical solutions for storage or disposal directly depend on SNF characteristics. The main SNF characteristics that shall be taken are as follows:

- Criticality of the system where SNF is stored to prevent self-sustaining nuclear chain reaction ;
- Content and activity of fission products, actinides and light elements;
- Neutron and gamma source terms;
- Decay heat.

In the course of estimation of the planned economic activity it is not required to know the particular SNF characteristics. They become relevant when the long-term storage or disposal method has to be chosen and for estimation of possible exposure of population and personnel during SNF transportation to storage or disposal area. Then, having the known characteristics of SNF the exposure that can impact the population from a container, a storage facility, or another object, accommodating SNF, is assessed. During the normal operation of the NPP the SNF is stored in cooling ponds, located adjacent to the reactor. The shielding of the ponds ensures that the environmental impact is negligible. In the analysis of environmental releases, presented in this EIA report, environmental releases from SNF cooling ponds, located adjacent to the reactor, were estimated in the total releases from the new NPP. Although the SNF characteristics were not directly used in the environmental impact assessment, but on the basis of the new NPP EIA program Table 6.2–6 gives tentative SNF characteristics for PWR (EPR, APWR, AP-1000), BWR (ESBWR) and PHWR (EC-6) reactors. The table shows the activities of fission products, normalized for a tone of uranium (the cooling time not taken into account). The list of radionuclides and their activities were submitted to illustrate that radiological characteristics of SNF produced in different types of reactors are different. According to the data, presented in Table 6.2–6, the values of radionuclide activities of the most fission products in the SNF produced by ESBWR are the highest, activities of EPR, APWR, AP-1000 are lower and do not differ significantly among themselves. Activities of SNF fission products of CANDU-6 are the lowest ones; however, as shown in Table 6.2–6, the amount of SNF produced by this reactor is the largest. Characteristics of SNF determine the selection of storage and disposal method, as well as of technology solutions. In case of SNF of the reactor EC-6, although the amount of fuel is the largest, due to lower activity of radionuclides present in SNF, thicknesses of shielding walls or other barriers of the SNF storage facilities may be smaller.

Table 6.2–6. Tentative radiological characteristics of SNF (Bq/tU)

Radio-nuclide	EPR	APWR	AP-1000	ESBWR	EC-6
Kr-87	2.61E+16	2.57E+16	2.22E+16	1.48E+17	1.48E+16
Kr-88	3.70E+16	3.62E+16	3.13E+16	2.09E+17	2.06E+16
Xe-133	8.35E+16	8.01E+16	8.32E+16	5.72E+17	5.43E+16
Xe-135	2.68E+16	2.45E+16	2.12E+16	1.89E+17	4.84E+15
I-131	4.02E+16	3.86E+16	4.22E+16	2.79E+17	2.73E+16
I-132	5.81E+16	5.57E+16	6.13E+16	4.05E+17	4.02E+16
I-134	9.19E+16	8.97E+16	9.55E+16	6.34E+17	6.27E+16
I-135	7.78E+16	7.50E+16	8.14E+16	5.38E+17	5.34E+16
Sb-127	5.20E+15	4.02E+15	4.51E+15	2.90E+16	2.30E+15
Te-131m	5.90E+15	5.52E+15	6.13E+15	4.00E+16	5.09E+15
Te-132	5.72E+16	5.49E+16	6.04E+16	-	3.91E+16
Sr-89	4.65E+16	4.47E+16	4.23E+16	2.80E+17	2.43E+16
Sr-90	4.89E+15	3.72E+15	3.64E+15	2.75E+16	4.18E+14
Ba-140	7.28E+16	7.12E+16	7.49E+16	4.98E+17	4.93E+16
Cs-134	1.87E+16	9.08E+15	8.49E+15	5.58E+16	2.34E+14
Cs-136	4.65E+15	2.47E+15	2.42E+15	1.94E+16	3.45E+14
Cs-137	7.14E+15	5.17E+15	4.95E+15	3.60E+16	5.82E+14
Ce-141	6.48E+16	6.72E+16	7.14E+16	4.73E+17	4.18E+16
Ce-143	6.59E+16	6.56E+16	6.66E+16	4.39E+17	4.32E+16
Ce-144	4.91E+16	5.09E+16	5.39E+16	3.83E+17	1.31E+16
Ru-103	7.00E+16	5.76E+16	6.35E+16	4.22E+17	3.45E+16
Ru-105	5.67E+16	3.78E+16	4.30E+16	2.82E+17	2.59E+16
Ru-106	4.13E+16	2.02E+16	2.09E+16	1.47E+17	4.20E+15
Zr-95	6.62E+16	7.12E+16	7.27E+16	5.04E+17	3.68E+16
Zr-97	7.02E+16	7.12E+16	7.18E+16	5.21E+17	4.52E+16
Nb-95	6.62E+16	7.18E+16	7.31E+16	5.07E+17	2.93E+16
La-140	7.34E+16	7.23E+16	7.97E+16	5.13E+17	-
La-141	6.97E+16	6.80E+16	7.09E+16	4.73E+17	-
La-142	6.79E+16	6.70E+16	6.87E+16	4.56E+17	-
Pr-143	6.53E+16	6.35E+16	6.39E+16	4.31E+17	-
Nd-147	2.73E+16	2.66E+16	2.84E+16	1.88E+17	-
Am-241	8.33E+12	7.07E+12	5.47E+12	4.79E+13	-
Cm-242	3.79E+15	1.75E+15	1.29E+15	1.13E+16	-

Measures such as fuel bundle design, correct geometrical positioning of fuel assemblies, operating controls of the environment of SNF, etc. are taken into consideration in order to prevent criticality occurrences during SNF handling, wet/dry storage or disposal.

After the SNF is discharged from the reactor core, it contains intensive sources of gamma and neutron radiation, therefore the continuous shielding to protect personnel and restrict direct radiation doses outside the NPP buildings is necessary. Initially such shielding is provided by the thick layer and the large volume of the water in the storage pools. The decay of the fission products also produces thermal energy, which have to be removed to protect a fuel rod from heating and from cladding damage, resulting in release of gases of fission products. Therefore SNF storage under water in a cooling pod also helps to control temperatures of fuel assemblies by means of convection cooling. As the radioactive decay of fission products, which are the main contributors of ionising irradiation, occurs with time, the intensity of radiation and residual heat reduces to values when SNF can be safely transferred to a dry storage facility.

Usually after 5-10 years the SNF from storage pools could be transferred to a dry storage or reprocessing facilities. The dry storage facility provides adequate containment and shielding barriers and decay heat removal systems. As mentioned earlier, presently SNF from Ignalina NPP is stored in interim dry storage facility.

The new NPP will have to construct a new SNF storage facility, which will accept the spent nuclear fuel from the new NPP reactors. As the experience of the existing INPP storage facility and of the new ISFSF being designed shows, radiological impact of such storage facilities on the population and the environment is negligible. E.g., an annual effective dose to a member of the critical group of the population at the location of the highest exposure (at the border of the proposed SPZ of the ISFSF) due to the new ISFSF is only 1.17×10^{-3} mSv (*EIA Report for ISFSF, 2008*).

The SNF stored at the new NPP storage facility will be further managed in accordance with the Radioactive Waste Management Strategy, approved by the resolution No. 860 of the Government of the Republic of Lithuania of September 3, 2008 (*State Journal, 2008, No. 105-4019*). As mentioned in section 6.2.2.1, pursuant to the eighth task of the 2nd objective possibilities of disposal, export for reprocessing or disposal of SNF in other countries should be analyzed. In accordance with Clause 9 of this Strategy, in 2002–2006 during the implementation of the Program of Assessment of Spent Nuclear Fuel and Long-lived Radioactive Waste Disposal Possibilities for 2003–2007, there were analyzed possibilities to arrange a deep geological repository in Lithuania, a regional deep geological repository of several European Union member states and to transfer SNF to the states that own proper installations and assume responsibility for the this waste. If the global policy on SNF transfer to other states is not changed or new SNF reprocessing technologies do not occur, not earlier than in 2030 it will be started to consider, what location of Lithuania shall be used for construction of a deep geological repository. If needed, a possibility to elongate the SNF storage at the storage facilities for a period over 50 years will be analyzed (taking into account the state of the storage facilities and containers).

According to the performance criterion of the 1st objective of Radioactive Waste Management Strategy (*State Journal, 2008, No. 105-4019*), the current value (2008) of radiological incidents and accidents during SNF and radioactive waste handling is 0, and the target value (2030) is 0.

6.3 DECOMMISSIONING WASTE

It is expected that the new NPP will operate about 60 years. After this time period the decommissioning process of the NPP will start. This process will generate radioactive and non-radioactive wastes of various physical states (solid, liquid, chemical and radiological properties). Since design lifetime of the existing INPP waste management facilities will be expired, the decommissioning waste of the new NPP will be processed in newly constructed appropriate radioactive waste management, treatment and storage facilities. Part of the resulting conditioned waste will be freely released; disposed of into the landfill, near-surface repositories or temporarily stored on site.

According to Swiss estimations, amounts of decommissioning waste depend on the thermal power installed. Amount (in terms of m^3) of decommissioning waste for PWR can be estimated multiplying thermal power (MW_{th}) of reactor by factor 3.03; for BWR multiplying by factor 3.5. BWRs produce slightly more waste than PWRs. Based on such rough estimation, the highest amount of decommissioning waste would be for ESBWR – about 16 000 m^3 per unit.

The International Atomic Energy Agency document (*IAEA TECDOC Series No. 1394*) provides guidance on planning and managing the decommissioning of nuclear facilities and the lessons learned.

6.3.1 Decommissioning strategies, procedures, methods and waste management

Specific decommissioning factors and constraints are analysed in IAEA document "Selection of Decommissioning Strategies" (*IAEA TECDOC Series No. 1478*) in order to provide support in the decommissioning strategy selection process. When selecting a proper decommissioning strategy in a specific facility, a range of general and site specific factors needs to be considered, typically, in a multi-attribute analysis. These factors include cost, health and safety issues and environmental impact, availability of resources, social impacts and stakeholder involvement, etc.

Three decommissioning strategies have been defined by the IAEA, namely: immediate dismantling, deferred dismantling and entombment (*Reisenweaver, D.W., 2003; Safety Standards Series No. WS-R-5*). "No action" is not regarded as an acceptable decommissioning strategy and therefore it will not be further discussed in this report.

Immediate dismantling commences shortly after shut down, if necessary following a short transition period to prepare for implementation of the decommissioning strategy. Decommissioning is expected to commence after the transition period and continues in phases or as a single project until an approved end state including the release of the facility or site from regulatory control has been reached.

As an alternative strategy, dismantling may be deferred for a period of up to several decades. Deferred dismantling is a strategy in which a facility or site is placed in a safe condition for a period of time, followed by decontamination and dismantling. During the deferred dismantling period, a surveillance and maintenance programme is implemented to ensure that the required level of safety is maintained. During the shutdown and transition phases, facility specific actions are necessary to reduce and isolate the source term (removal of spent fuel, conditioning of remaining operational or legacy waste, etc.) in order to prepare the facility/site for the deferred dismantling period.

Entombment is a strategy in which the remaining radioactive material is permanently encapsulated on site. A low- and intermediate-level waste repository is effectively established and the requirements and controls for the establishment, operation and closure of waste repositories are applicable.

Although evaluation of the prevailing factors could clearly indicate one of the above mentioned strategies, constraints and overruling factors may occur in practice, and these necessitate a combination of strategies or exclude one or more strategies from consideration.

The availability and use of suitable technology are important parts of decommissioning planning and can influence the selection of a strategy. Site-specific features may demand technology development and adaptation, but in many cases mature technology is commercially available.

Decommissioning activities are performed with an optimized approach to achieving a progressive and systematic reduction in radiological hazards, and are undertaken on the basis of planning and assessment to ensure the safety of workers and the public and protection of the environment, both during and after decommissioning operations (*Safety Standards Series No. WS-R-5*).

When selecting a strategy for the new NPP decommissioning, priority must be given to immediate dismantling. If immediate dismantling is not the most acceptable strategy to decommission the NPP, the operating organization can choose the deferred dismantling after safe conservation period or its entombment for an indefinite period (after submission of a justification for the selection). In case the deferred dismantling of the

NPP is chosen, the operating organization shall also demonstrate that the plant will be maintained in a safe configuration at all times, changes of requirements related to storage of the decommissioning information, application of technologies and financing will be considered and the plant will be adequately decommissioned in the future and that no undue burdens will be imposed on future generations (*Safety Standards Series No. WS-R-5*).

The INPP example also confirms the necessity to give priority to immediate dismantling of the NNPP. The Government of the Republic of Lithuania, seeking to ensure that the INPP decommissioning would not cause serious long-term social, economic, financial and environmental consequences, by its resolution No. 1848 of November 26, 2002 (*State Journal, 2002, No. 114-5095*) established that the decommissioning of the first INPP unit shall be carried out by means of the immediate dismantling.

The operating organization of the new NPP shall implement the decommissioning and related waste management activities in compliance with the Lithuanian safety standards and requirements. The operating organization shall be responsible for all aspects of safety and environmental protection during the decommissioning activities.

In order to provide an adequate level of safety, the operating organization shall, inter alia, prepare and implement appropriate safety procedures; apply good engineering practice; ensure that staff are properly trained and qualified and are competent; and keep and submit records and reports as required by the regulatory body.

Decontamination and dismantling techniques shall be chosen such that the protection of workers, the public and the environment is optimized and the generation of waste is minimized. Decommissioning activities such as decontamination, cutting and handling of large equipment and the progressive dismantling or removal of safety systems have the potential for creating new hazards. The impacts on safety of these activities shall be assessed and managed so that these hazards are mitigated and are kept within acceptable limits and constraints.

6.3.2 Decommissioning plan and waste management

During the design stage of the new NPP an initial decommissioning plan should be prepared before the operating licence is issued. The initial decommissioning plan should state in general terms that the plant can be taken out of service, and provide an outline of decommissioning methods and technologies. The initial decommissioning plan must specify the likely quantity of waste and provide an estimate of decommissioning costs.

The decommissioning plan shall be periodically updated. The updates are intended to reduce the impact of decommissioning on the public and the environment, and to ease the process by allowing for changes in decommissioning technologies and in radioactive waste management. The decommissioning plan must be updated at least every 5 years. Ongoing decommissioning plans should be corrected if systems and installations have been significantly altered, or if incidents or accidents have taken place resulting in unforeseen contamination of the NNPP site and its systems.

If a decision is made to decommission the nuclear power plant or one of its units it is obligatory, five years in advance, to submit to VATESI a decommissioning program and final decommissioning plan after co-ordinating it with the Ministry of Economy, the Ministry of the Environment, the Ministry of Health, the Ministry of Social Security and Labour, the county governor and the local authority of the territory which, in its entirety or in part, is within the facility sanitary protection zone. The Program should contain information about dismantling and conservation of equipments, management of radioactive materials and radioactive waste as well as later control and supervision of the object.

Ministry of Environment considers that the preliminary decommissioning plan and the final decommissioning plan complies with the definition of “plans and programs”, given in the Description of the Procedure of Strategic Environmental Impact Assessment of Plans and Programs (hereafter – the Description of the SEIA Procedure) (Decision of the Government of the Republic of Lithuania No. 967 of August 18, 2004 (*State Journal, 2004, No. 130-4650*)). The preliminary and the final decommissioning plan of the new nuclear power plant will govern the framework of development of the projects of economic activities included into Annex 1 or 2 of the Republic of Lithuania Law on Environmental Impact Assessment of Planned Economic Activities, for example, arrangement of intermediate storage facilities of radioactive waste and/or installation or expansion of radioactive waste disposal facilities. In such cases the requirements in Paragraphs 7.1 or 11.1 of the Description of the SEIA Procedure should be applied. During the development of the aforementioned plans procedures of strategic environmental impact assessment shall be carried out, and the documents of the strategic environmental impact assessment would form a constituent of the preliminary and the final decommissioning plan.

6.3.3 Decommissioning and waste management cost and fund

Once the reactor has started operation, the core is irradiated, and the primary system components have become radioactive, the cost of decommissioning a nuclear reactor is basically fixed and is permanent. Other factors may change the overall costs somewhat but the general level of decommissioning cost would remain similar. Factors during the operation phase that could lead to an increase in the eventual decommissioning cost could be, for example, potential degradation in operational performance or a major contamination event. On the other hand, innovations and developments in decontamination technologies could reduce the decommissioning cost (*Devgun J. S., 2008*). One important factor that has the potential to substantially change the decommissioning cost is the availability of facilities and cost of the radioactive waste disposal as well as the facilities for management and storage of spent nuclear fuel. The new NPP will have to install a new spent fuel storage facility since the present storage facility and the facility under construction will be completely filled by the year of the decommissioning start.

The operating organization of the new NPP shall accumulate and have sufficient funds for the decommissioning and radioactive waste management. The operating organization of the new NPP shall ensure that the decommissioning funds will be sufficient in case of an accident, as well.

The decommissioning funds will be accumulated over the operating life of the reactor (as a levy on a per kWh basis) and held in a decommissioning fund. The decommissioning cost for an individual reactor can range from approximately $300 million to over $600 million depending on the reactor and the site specific factors. The average decontamination & decommissioning (D&D) cost for a full size reactor is closer to $600 million per reactor (*Devgun J. S., 2008*). This is a significant portion of the overall life cycle costs of the reactor. The cost of decommissioning is proportional to the amount of decommissioning waste.

It can be concluded that while several factors could affect the overall decommissioning strategy and decommissioning cost, one way to reduce the decommissioning and radioactive waste management cost would be to optimize the design of the systems and structures for eventual decommissioning.

6.3.4 Decommissioning stages and waste management

The NNPP decommissioning involves the implementation of legal, organizational, and technical measures of the NNPP management, when a decision is taken not to use it for its intended purpose anymore. The NNPP management refers to exercise of the NNPP decontamination, dismantling, the management of decommissioning residues and waste, the site clean-up and other steps in order to achieve not restricted use of the site or a permission to construct other nuclear facilities on the site. The decommissioning stages are parts of the overall decommissioning project, selected at the NNPP discretion. During each stage the physical state of the NNPP and the equipment is defined and the maintenance required at the beginning, during and at the end of the stage is determined.

The first stage usually includes the decommissioning preparation works. 5 years prior to the planned final shutdown of a power unit a final decommissioning plan shall be submitted to VATESI for approval, a VATESI license for decommissioning shall be obtained, and appropriate permissions from state authorities and local government authorities etc. shall be obtained. Decommissioning can be carried out only if decommissioning residues and radioactive waste can be safely managed, and the destiny of radioactive waste before disposal is envisaged. To this end, as far as during the operation, when planning the decommissioning it is necessary to establish categories, forms, groups and respective quantities of radioactive waste that will be produced. Based on this information, the most appropriate strategy for radioactive waste management, as well as radioactive waste pretreatment, treatment, conditioning, transport, storage and disposal methods are selected.

During the stage of final shutdown actions of normal operation, set out in the operating license, can be carried out. These include SNF unloading and departure from the unit, operational waste management, routine decontamination of elements. SNF unloading from the reactor can begin only after adequate approval of the safety justification by VATESI and provision of criticality control. Unless SNF is unloaded from the reactor and removed from the cooling ponds, the systems important for safety of the reactor and the ponds and the supporting systems cannot be dismantled or eliminated. Before the disconnection of the systems supporting the functioning of the NNPP SNF ponds and the dismantling of the ponds, the related impact on the existing interim SNF stores shall be assessed.

When selecting methods for decontamination and dismantling the use of conventional methods is preferred. During decontamination and dismantling as low radioactive waste production as possible shall be assured, thus decommissioning residues contaminated with radioactive substances can be recycled, reused or disposed in accordance with the clearance principles. The decommissioning residues, which the clearance principle cannot be applied to or when this is not expedient, are managed as radioactive waste.

The NNPP buildings and its site can be free released in part or in full, if contamination levels are lower than the determined ones. These values are offered by the NNPP, they are approved under the procedures set out in the Lithuanian legislation. When determining the levels of contamination and carrying out control, duration of exposure and exposure paths of the critical group are taken into account. Control by an accredited public authority may be carried out for a specified period if some of the buildings or the site is used.

6.3.5 Decommissioning considerations during design

The main factors driving the design of the new reactors are the enhanced safety features, safeguards considerations, and the economic factors. Optimization of the facility and system design for decommissioning is generally not a high priority. This means that decommissioning considerations are not being fully represented as a design item in the new reactor design process.

Eventually all reactors, including the ones under construction or planned, will need to be decommissioned at the end of their lifecycle. The fact that the decommissioning phase for the new reactors may take sixty or more years has clearly led to decommissioning considerations being seen as a low priority in the design and the regulatory process. However, the benefits of such considerations early in the design stage are many. Incorporating decommissioning considerations into the designs of the new reactors can ensure that the eventual decommissioning can be completed in shorter time frame, with minimum generation of radioactive waste, and with better radiological safety.

Some of the reactor designs have been successfully optimized in this regard. Specific interest to the design phase of the new reactors should be given to two factors: system design and facility design (*Devgun J. S., 2008*).

6.3.5.1 System design with the aim to minimize waste amounts

An emphasis on the following considerations will optimize the project from the very beginning towards eventual decommissioning. These include:

- Reduction in the system components;
- Modular designs of systems;
- More reliance on passive safety systems;
- Use of contained systems (thus, minimizing the potential for cross contamination);
- Better designs of piping systems, HVAC systems, and sumps and drains.

The experience with decommissioning projects so far shows that approximately 65 to 75 percent of the costs are related to removal activities (systems and structures – decontamination, demolition and removal), disposal of components and low level waste, dry spent fuel storage facility construction, and staffing. The remaining costs account for the other items such as security services, radiological surveys, taxes and other miscellaneous items.

System design optimization with respect to decommissioning considerations can reduce the eventual decommissioning cost of both the removal activities and the disposal costs. Both of these are a major portion of the overall decommissioning cost. A reduction in the system components and a modular design that will facilitate dismantlement activities will clearly reduce the costs of decommissioning. An additional benefit of an optimized design will be the reduction in the overall radiation exposure to the decommissioning workers.

6.3.5.2 Facility design with the aim to minimize waste amounts

An emphasis on the structural design and the architectural design considerations will optimize the project from the very beginning towards eventual decommissioning. These include:

- Minimizing the foot print of structures;
- Modular designs of structures;

- Designing for large component removal.

The disposal cost of the structural debris is substantial, especially if it has to be treated as low level radioactive waste. Even though it may be possible to segregate the radioactive and non-radioactive debris, the licensing issues, the release criteria and other factors may influence the disposal of such materials. Thus, minimizing the structures that will be eventually demolished reduces the overall volume of the material that will need to be disposed.

The issue of designing for major component removal is significant because from the industry experience so far, the preference has been to avoid segmenting the reactor vessel. This reduces costs and reduces the radiation dose to decommissioning workers. Thus, a design optimized during construction that will allow for major component removal will facilitate decommissioning (*Devgun J. S., 2008*).

6.3.5.3 Summary key factors for minimization of waste amounts

Based on the extensive decommissioning experience that is now available, it is possible to summarize key factors that are relevant to the new reactors and that would facilitate their future decommissioning and radioactive waste management:

- Incorporation of modular concepts in structural design;
- Innovations in equipment, materials, and system layout;
- Lessons from decommissioning projects, especially in terms of major component removal;
- Access to highly contaminated components for decontamination;
- Consideration of the total life cycle including decommissioning while designing equipment and structures and while implementing modifications during the operating life of the reactor;
- Minimization of underground drains and buried piping as much as possible;
- Designs that will prevent or minimize the potential for leaks and spills and that will allow for their early detection;
- Minimization of future waste volume generation during the decommissioning phase of the reactor;
- Good historical site assessment with records of any spills, radiological contamination, soil excavations, and disposals during the plant operation;
- Design assessment in terms of estimated decommissioning cost per MW_e effectiveness;
- Design concepts incorporating early selection of the decommissioning option;
- Decommissioning engineers embedded on the reactor design team with a specific mission to optimize the reactor systems and structures for eventual decontamination and decommissioning;
- Developments in release criteria for the decommissioned sites and materials.

Designing D&D into the new reactor designs is necessary to ensure that the tail end costs of the nuclear power are manageable. Such considerations during the design stage will facilitate a more cost-effective, safe and timely decommissioning of the facility and radioactive waste management when a reactor is eventually retired.

7 PRESENT STATE OF THE ENVIRONMENT, ASSESSMENT OF POTENTIAL IMPACTS OF THE PROPOSED ECONOMIC ACTIVITY AND MITIGATION MEASURES

7.1 THE STATE OF WATERS

7.1.1 Present state of the environment

7.1.1.1 Hydrogeological conditions

The new NPP area is located in the recharge area of the eastern part of the Baltic artesian basin. Hydrogeological conditions of the area are described based on the investigations carried out around the cross-section AA' presented in Figure 7.1-1. Three different hydrodynamic zones characterized by active, slower and slow water exchange are found in the area. The active water exchange zone is separated from the slower water exchange zone by the 86–98 m thick regional Middle Devonian (Narva) aquitard, located at a depth of 165–230 m. It is composed of loam, clay, domerite and clayey dolomite. The slower water exchange zone is separated from slow water exchange zone by the 170–200 m thick regional Silurian–Ordovican aquitard, located at a depth of 220–297 m (*Marcinkevicius et al., 1995*).

The thickness of the Quaternary aquifer system varies from 60 to 260 meters (mostly between 85–105 m) including layers with low water permeability. This aquifer system consists of seven aquifers: the upper shallow unconfined aquifer and six confined aquifers attributed to different glaciofluvial intertill deposits from Pleistocene age. The detailed ages of these deposits in regional schemes are attributed to Baltija–Gruda (aqIII), Gruda–Medininkai (aqIII-II), Medininkai–Zemaitija (aqII), Zemaitija–Dainava (aqII-I), Dainava–Dzukija (aqI1) interglacials and Dzukija (aqI2) glacial (Figure 7.1-2).

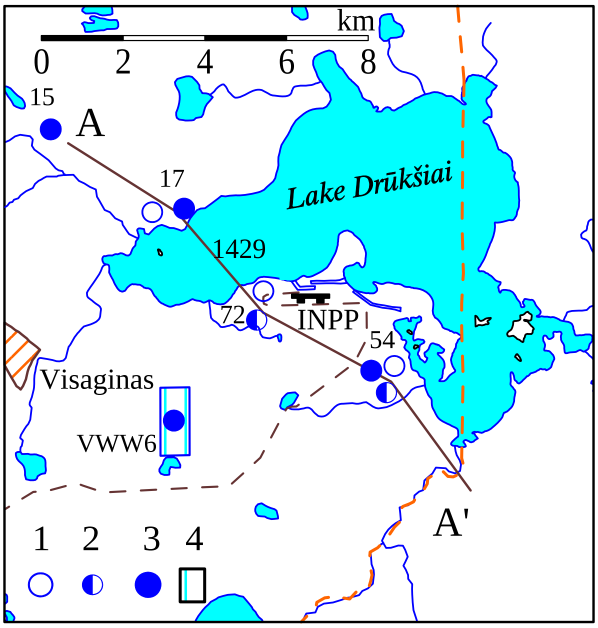


Figure 7.1-1. Location of hydrogeological cross-section AA' in the area of the new NPP: Symbols 1,2 and 3 present the observation wells (and the sample point number) of the previous monitoring system (1 – unconfined aquifer, 2 – confined Quaternary aquifer, 3 – confined Upper-Middle Devonian aquifer) and the symbol 4 presents the well-field of Visaginas Energija.

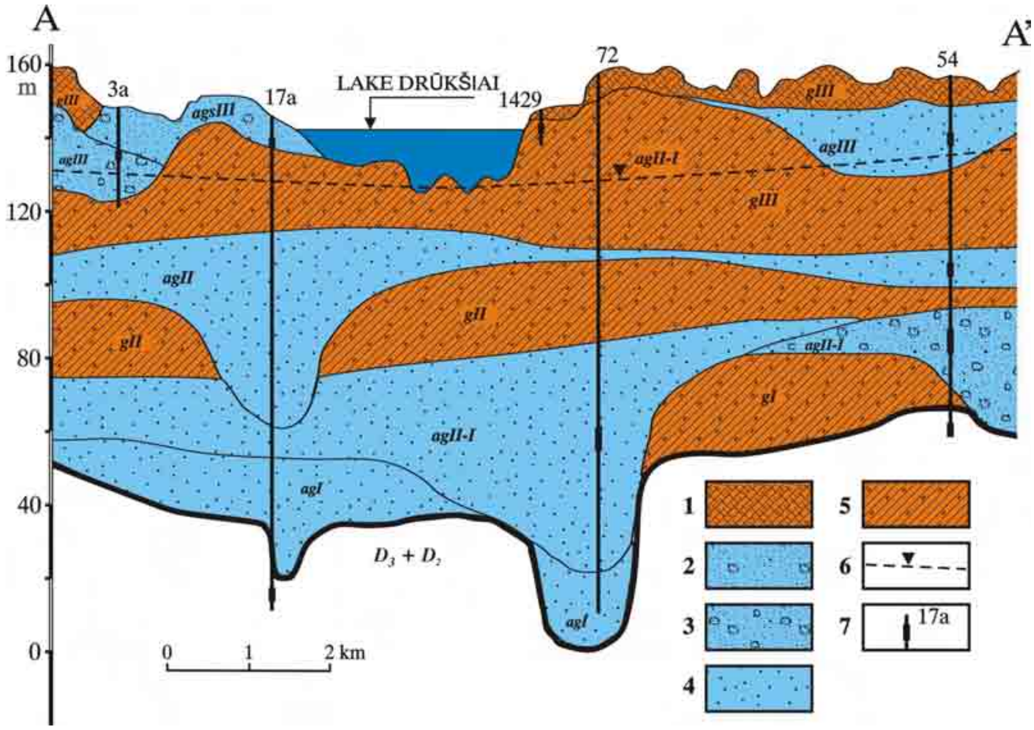


Figure 7.1-2. Hydrogeological cross-section AA' (modified after *Marcinkevicius et al. 1995*) of the new NPP area (location of the cross-section is shown in Figure 7.1-10): 1 – fissured till deposits; 2 – unconfined aquifer (fine sand with gravel); 3 – unconfined and confined aquifer (various sand with gravel); 4 – confined aquifer (various sand with gravel and interlayers of silt and clay); 5 – aquitard (till deposits); 6 – groundwater level of confined aquifer agII-I; 7 – observation well with filter interval and its number.

The confined Quaternary aquifers are separated from each other by low permeability till bodies (aquitards) of sandy loam and clayey loam with lenses of sand and gravel. The thickness of different aquitards varies from 0.5 to 50–70 m, mostly – from 10–15 to 25–30 m. The aquifers attributed to the intertill deposits are composed of sand, gravel, and, in some paleovalleys, of gravel and pebble. The thicknesses of different aquifers vary from 0.3–2 m to 20–40 m, and in paleovalleys they can be over 100 meters thick (*Marcinkevicius et al., 1995*). Unconfined groundwater occurs in bog (peat) and glaciofluvial deposits (vary-grained sand, gravel and pebbles) as well as in the fissured upper part of the eroded sandy and clayey loam.

The above mentioned aquifers constitute a common hydraulic system which is located in a water recharge area. The piezometric level of Upper-Middle Devon aquifer in the greater part of the region is lower than piezometric level of unconfined groundwater and confined intertill aquifers, which indicates that ground water is replenished by recharge. Prevailing lateral groundwater flow direction is to the north, north-east towards the Lake Druksiai and in wider region towards the Daugava River in north.

Groundwater in the main aquifers is fresh, magnesium–calcium bicarbonate type and the concentration of total dissolved solids (TDS) varies from 0.3 to 0.5 g/l. The TDS values for groundwater within the till fissures are higher, ranging between 0.58 and 0.85 g/l (*Marcinkevicius et al., 1995; Hidroprojektas Report, 2006a; Hidroprojektas Report, 2006b*). Total hardness of groundwater varies from 5.19 to 5.95 meq/l and conductivity from 610 to 705 μS/cm.

In the new NPP sites unconfined groundwater is attributed to upper part of Quaternary succession composed of till and intertill deposits. In the first case precipitation water infiltrates into fissured zones and sandy inhomogeneities of till body mostly near surface, and also into deeper laying sandy lenses (sandy loam, sandy clay). Confined (or sometimes unconfined) groundwater is attributed to Quaternary intertill deposits composed mostly of silt and sand. Precipitation water infiltrating into Quaternary layers via unsaturated zone dissolves anions and cations of the soil and of the saturated zone and becomes enriched by organic matter and soil gases, governs the thermodynamic state of system "water-solid", which forms water of calcium–magnesium bicarbonate type.

The following chemical parameters are typical for groundwater attributed to glaciolacustrine, glacial and intertill deposits: concentration of bicarbonate-ions reaches 400–600 mg/l, concentration of total dissolved solids 0.6–1.2 g/l, CO_2 partial pressure – 10–1.2 ÷ 10–1.5 atm.

Some chemical components of groundwater are limited by Lithuanian Hygiene Standard HN 24:2003 "Safety and quality requirements for drinking water"(*State Journal, 2007, Nr. 127-5194*), if groundwater would be considered as drinking water. Confined groundwater mostly satisfies requirements, whereas unconfined groundwater, which is the case for this region, does not always fulfil the requirements for drinking water because of higher concentration of NH_4^+, NO_2^-, organic matter (in terms of permanganate number), Fe, Mn and Ni. These features of groundwater quality in a whole region are mostly determined by natural processes and in case of unconfined groundwater its abstraction by shallow dug-wells with improper technical control is important as well.

More detailed description of the groundwater at the alternative sites and assessment of the impacts on groundwater are further discussed in Section 7.3.

7.1.1.2 Hydrological conditions

Lake Druksiai belongs to the Dauguva catchment area. It outflows to the Baltic Sea via a 550 km long river continuum: Druksiai → Prorva → Druksa → Dysna → Daugava → Gulf of Riga.

The catchment area of Lake Druksiai (Figure 7.1-3) is only 564 km^2. Its greatest length, from south-west to north-east, is 40 km, maximum width is 30 km and average width is 15 km. Lake percentage is 16 %, which is exceptionally high in Lithuania. A greater part of the area is occupied by forests (38 %). The arable lands account for 26 % and bogs for 16 %. The area is dominated by sand, clay loam and sandy loam soils, which are the reason for varying water filtration conditions in different parts of the catchment area. (*Hydro-physical Basis State in Lake Druksiai, 1989*).

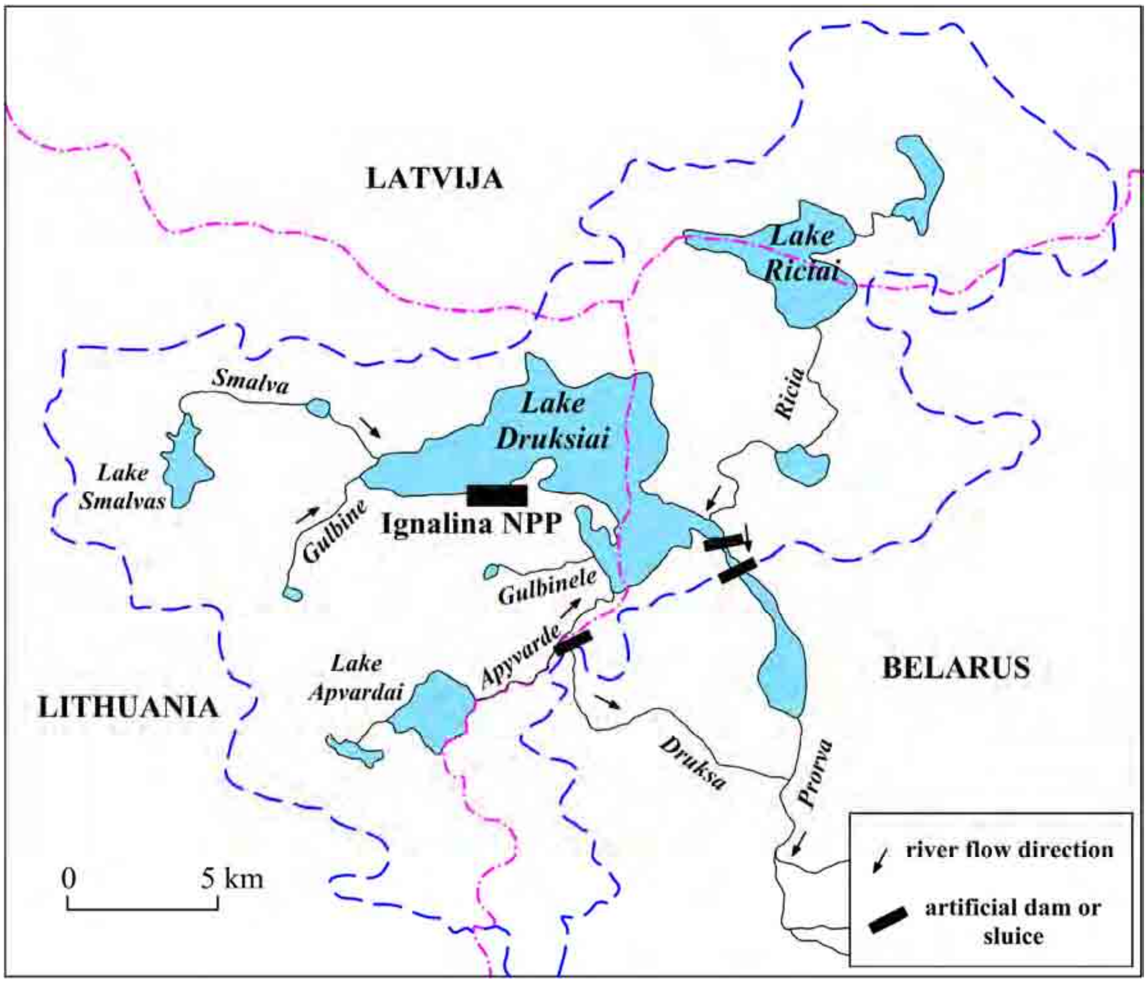


Figure 7.1-3. Scheme of Lake Druksiai catchment area.

Lake Druksiai has 11 tributaries and one river that outflows it (the Prorva). The main rivers connected to Lake Druksiai are the Ricia (Ricianka), the Apyvarde and the Smalva (Table 7.1–1).

Table 7.1–1. Lake Druksiai tributaries and their characteristics.

River	Length of river, km	Catchment area, km²	Run-off, m^3/s
Apyvarde	11.4	156.6	0.861
Gulbinele	5.9	6.3	0.035
D-1	4.0	4.3	0.024
D-2	4.9	5.6	0.031
Gulbine	8.0	33.0	0.181
Smalva	11.9	88.3	0.485
D-3	3.7	6.6	0.036
D-4	8.0	16.5	0.091
D-5	3.2	3.3	0.018
D-6	2.0	3.3	0.018
Ricia (Ricianka)	20.3	215.3	1.184

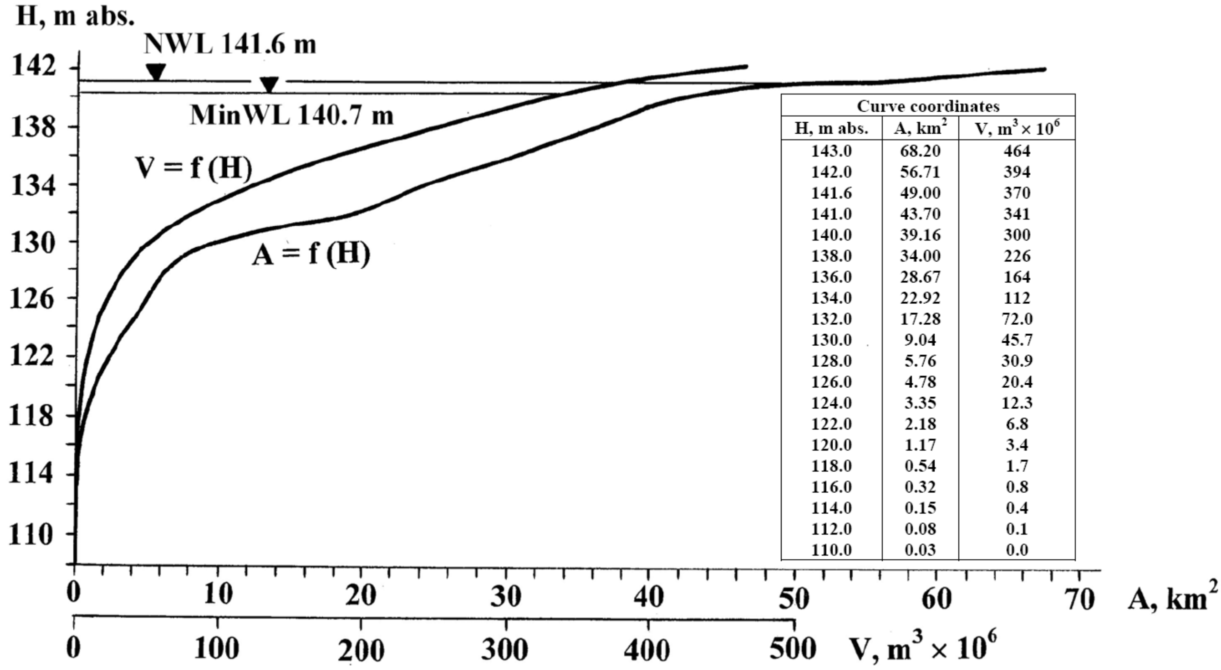
Lake Druksiai is the largest lake in Lithuania with a total volume of appr. 369×10^6 m^3.

Lake water surface area at normal water level (141.6 m) is 49 km^2, dependence between lake surface area and lake volume on lake water level is given in Figure 7.1-4 (*The main rules of water usage of Lake Druksiai, 1993*). If the lake water level drops down to the minimum allowable level (i.e. 140.7 m), the lake surface area will decrease to 42 km^2, and if the lake water level rises up to the maximum allowable level (i.e. 142.3 m), the lake surface area will increase to 60 km^2. The greatest depth of the lake is 33 m and the average depth is 7 m. The southern part of the lake is the shallowest (3–7 m in depth), whereas greater depths are typical for the central, west and north parts of the lake. The length of the lake is 14.3 km, the maximum width 5.3 km and the perimeter 60.5 km. The lake is characterized by relatively slow water exchange rate. The main outflow is the River Prorva in the southern part of the lake. (*Hydro-physical Basis State in Lake Druksiai 1989; Basis State of Aquatic Animal Populations and Communities in Lake Druksiai 1986; Jakimaviciute et al. 1999, Jurgeleviciene et al., 1983*). The main hydrological parameters of the lake are given in Table 7.1–2.

Table 7.1–2. The main hydrological parameters of Lake Druksiai (at normal water level according to *Hydrophysical basis state in Lake Druksiai, 1989, Ecosystem of the water-cooling reservoir of Ignalina nuclear power-station at the initial stage of its operation, 1992*).

Parameter	Value
Catchment area, km^2	564
Surface area , km^2	49
Average annual run-off, m^3/year	105.07×10^6
Average run-off, m^3/s	3.33
95% probability run-off, m^3/s	1.69
10% probability run-off, m^3/s	4.89
Average precipitation, mm/year	592
Average evaporation from the surface, mm/year	600
Mean water level, m above sea level	141.6
Minimum allowable water level, m above sea level	140.7
Maximum allowable water level, m above sea level	142.3
Regulation height*, m	0.90
Regulating volume of the lake*, m^3	43×10^6
Total volume of the lake, m^3	369×10^6

*Regulation height and regulating volume are given as a difference between normal (mean) water level and minimum allowable water level.



Curve coordinates		
H, m abs.	A, km^2	V, m^3 × 10^6
143.0	68.20	464
142.0	56.71	394
141.6	49.00	370
141.0	43.70	341
140.0	39.16	300
138.0	34.00	226
136.0	28.67	164
134.0	22.92	112
132.0	17.28	72.0
130.0	9.04	45.7
128.0	5.76	30.9
126.0	4.78	20.4
124.0	3.35	12.3
122.0	2.18	6.8
120.0	1.17	3.4
118.0	0.54	1.7
116.0	0.32	0.8
114.0	0.15	0.4
112.0	0.08	0.1
110.0	0.03	0.0

Figure 7.1-4. Dependence of lake surface area (A) and water volume (V) on Lake Druksiai water level (H) (*Main provisions on using instructions of Lake Druksiai water resources consumption, 1993*).

7.1.1.3 Water regime of Lake Druksiai

Nearly all surface discharge (74 %) enters the southern part of Lake Druksiai via rivers Ricia (Ricianka) and Apyvarde. The rest of the surface discharge enters the western part of the lake via tributaries Smalva and Gulbine. The outlet of the river Prorva is located at the southern part of the lake. The most intensive water exchange takes place in the southern part of the lake.

The water regime of Lake Druksiai is affected by natural and anthropogenic factors. The main natural factors are surface inflow (73 %) and outflow (77 %). Due to the large surface area precipitation (24 %) and evaporation (23 %) are also significant. The inflow of unconfined and semi-confined groundwater is insignificant (less than 3 %). Outflow to the deeper laying ground water horizons is considered to be very low due to the permeability properties of bed sediments and deposits (*Hydro-physical Basis State in Lake Druksiai, 1989*).

Anthropogenic factors affecting the water regime of Lake Druksiai are regulation of the outflow by the dams (Figure 7.1-3) and cooling water discharge of the NPP. The lake is regulated to ensure a sufficient water supply for cooling of the INPP. Lake Druksiai outflowed via River Druksa until it was dammed downstream the River Apyvarde in 1953 to direct the discharge from the Apyvarde basin to Lake Druksiai (*Mazeika et al., 2006*). In the same year a run-off regulation sluice (“Object 500”) was installed on the River Prorva, to regulate the water level of Lake Druksiai. Approximately 1.5 km downstream, between the lakes Stavokas and Abaliai a hydroelectric power plant (HPP) “Tautu draugyste” was built in 1953. The HPP was taken out of operation in 1982. After construction of Ignalina NPP Lake Druksiai water level is regulated using structures of the former HPP.

Evaporation from the lake surface has increased due to the heat entering the lake with INPP cooling water. The average increase in evaporation was 49 % (from 31 % to 67 %) during the warm period of 1984-1996 (V-VIII months) compared to evaporation rates before the construction of INPP (*Kriauciuniene and Sarauskiene, 2008*).

An estimation of the annual water balance of Lake Druksiai is presented in Table 7.1–3 both for regulated and unregulated lake. Water balance of the unregulated lake has been calculated for an average hydrological year. The main inputs are surface inflow (MQ=3.27 m^3/s) and precipitation (592 mm). Groundwater inflow is quite insignificant. The main output is the river outflow (MQ= 3.33 m^3/s). The natural annual evaporation rate is in average 600 mm. Water balance for the regulated lake has been calculated for a dry year with a 1-in-20 year return period (95 % probability). It is lower than for the unregulated lake (Q= 0.64 m^3/s[1]) since the run-off is regulated by the dam at the river Prorva. Due to the regulation the volume available for additional evaporation is larger than in the unregulated lake. In a dry year approximately 33.1 mln. m^3 of water is available for the additional evaporation before the water level drops below the normal (141.6 m).

Table 7.1–3. The annual water balance (mln. m^3) for Lake Druksiai.

Parameter	Unregulated, average hydrological year (Outflow MQ = 3.33)	Regulated, average hydrological year (Outflow MinQ = 0.64)	Regulated, dry hydrological year (Outflow MinQ = 0.64)
Surface inflow	103	103	51
Ground water inflow	3.5	3.5	3.5
Precipitation	29	29	22.3
Total input	**135.5**	**135.5**	**76.8**
Outflow	105.1	20.2	20.2
Evaporation	29.4	29.4	23.5
Total output*	**134.5**	**49.6**	**43.7**
Available water volume**		**85.9**	**33.1**

*Approximate amount of ground run-off value or surface water inflow/outflow data, that have been calculated using river-analogue, could be the reasons of water balance inaccuracy (1.004 mln. m^3).
**The available water volume is the volume available above the normal water level (141.6 m) and does not include the regulating volume

The impact of cooling water to the evaporation has been assessed by a regression equation based on actual measurements of the lake evaporation and the INPP operation data. The evaporation measurements were carried out during a warm period. The impact of the NPP on evaporation from the lake is given by ΔE = f (N), where N = NPP operating capacity (in GW). In a range of N = 1–2500 MW the dependence between evaporation and operating capacity can be approximated by linear equation (*Janukeniene 1992*) (Figure 7.1-5):

$$\Delta E_{monthly} = 21.4\, N_{\mathrm{monthly}} + 4.9.$$

[1] By order No D1-382 signed in July 29, 2005 (*State Journal, 2005, No 94-3508*) of Minister of Environment of Lithuania, this is a minimum acceptable river discharge (for regulated river).

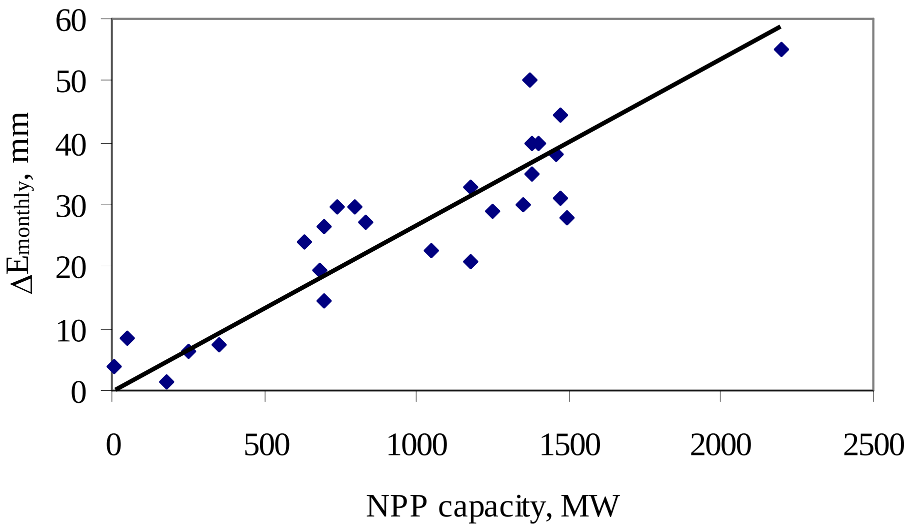


Figure 7.1-5. Correlation between the additional monthly evaporation from Lake Druksiai and the operating capacity of NPP.

The adequacy of the water resources for cooling purposes of the new NPP, with a maximum power output of 3 400 MW, can be assessed based on the regression equation and water balance calculation. According to experts (*State of INPP cooling water reservoir ecosystem during initial operational period, 1992*) it can be estimated that 1000 MW rise in NPP load corresponds to 14.3 million m^3 increase in evaporation.

The total amount of evaporation is not dependent of the cooling system selected. Evaporation losses per energy unit are approximately the same from cooling towers as from the lake surface in direct cooling.

According to water balance estimation, the amount of water available in a dry year (water height remains at normal level) for cooling is app. 33.1 million m^3. In addition the regulation volume of 43.0 million m^3 is also available for cooling (before the lake level drops below the minimum allowable level). The annual input of 33.1 million m^3 and the regulating volume of 43.0 million m^3 would give adequate water supply in all the evaluated scenarios for about three successive dry years (with a 1-in-20 year return period).

The presented assessment should be considered preliminary. A more detailed hydrological study of the water resources will be carried out as a part of the technical design in the project, when the enhanced monitoring has provided additional information.

7.1.1.4 Water level and discharge monitoring by the INNP

The purpose of the hydraulic structures located within the former hydroelectric power plant "Tautu draugyste" on the river Prorva and "Object 500" is to maintain the specified water levels of Lake Druksiai, to pass water of spring flooding and flash floods after excessive rain, as well as to ensure the minimum acceptable flow of water. The mean water level is 141.6 m, the minimum - 140.7 m and the maximum - 142.3 m above sea level, the minimum acceptable flow - Q = 0.64 m^3/s (*Technical specification of the hydraulic structures, INPP, code PTOed-0917-23B2*).

The regulating "Object 500" on the river Prorva is attributed to Class 1 of capital equipment, it consists of a wide threshold water gate of two intervals fitted with segmented regulating barriers. “Object 500” has a device ensuring the minimum acceptable flow (Q = 0.64 m^3/s). At present “Object 500” is not used for regulation of Lake Druksiai water level, it performs the interim function of water throughput from Lake Druksiai to the hydraulic structure within the former hydroelectric plant “Tautu draugyste”. The segmented barriers of “Object 500” are raised to the top and fixed with detents, which are locked. Regulation with the help of the barriers of “Object 500” is only possible in emergency cases by special instructions of INPP management.

The regulation of the water level of Lake Druksiai is carried out using the structures of the former hydroelectric power plant located on the river Prorva, 1.5 km downstream from “Object 500”, past Lake Stavokas. When the sluices (metal panels) of the former hydroelectric power plant are raised, water from Lake Stavokas is discharged from below the sluice; it gets into circular holes of the dismantled turbines, and then free falls into the lower pool, from where with the river Prorva it enters Lake Abaliai (*Belarus*. Obole). The diagram of dependence of the passed outflow on the height of the sluice lifting above the threshold of the water gate at mean water level (141.6 m) is presented in Figure 7.1-6.

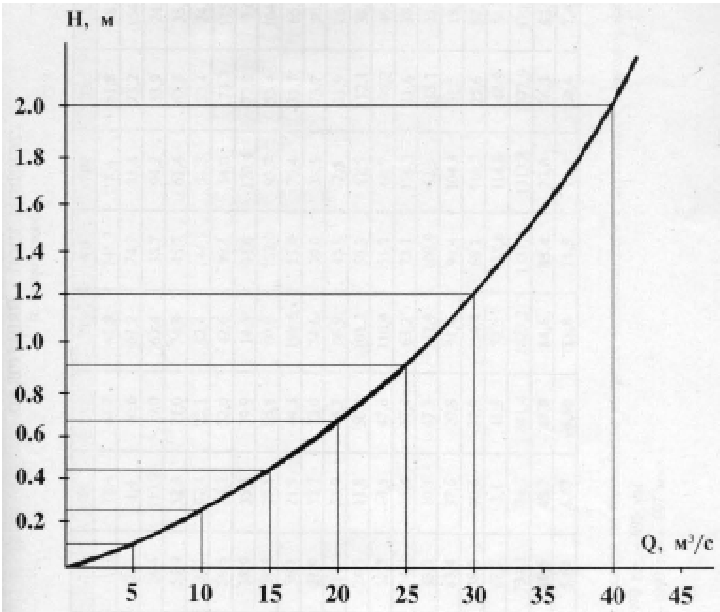


Figure 7.1-6. Dependence of the outflow passed by the hydraulic structure on the height of the sluice lifting above the threshold of the water gate at the mean water level (141.6 m): Q – passed outflow, m^3/s; H – height of the sluice lifting, m (Technical specification of the hydraulic structures, INPP, code *PTOed-0917-23B2*).

The INPP document “Operating Instruction for the Hydraulic Structure ‘500’ and for the Hydraulic Structure on the Base of the Former Hydroelectric Power Plant ‘Tautu draugyste’ (*INPP code PTOed-0912-54B6*) provides the INPP staff with the measurement methodology and sets out the requirements for reliable and safe operation of the hydraulic structures. The hydraulic structures are attributed to the systems of normal operation not influencing the safety of the nuclear power plant. The instruction indicates that using the diagram (Figure 7.1-6) the former hydroelectrical power plant gate opening height is determined so that the water level of Lake Druksiai is maintained at the mean water level (141.6 m). Two sluices are used for regulation of the water level of Lake Druksiai, and the third one – to discharge excessive water if during a flood the maximum water level (142.3 m) is reached or if an instruction of the INPP management is received. The sluices can be closed only so much that the minimum acceptable flow Q = 0.64 m^3/s is assured.

The INPP document “Procedure on Organization of Maintenance of Hydraulic Structures” (*INPP code PTOed-1012-35B7*) sets out the requirements for maintenance, surveillance, filling of journals of technical inspection of the structures, etc.

Based on the monitoring results from years 1999–2008, the lake level has remained quite constant (Figure 7.1-7). During this observation period the annual variation has usually been a couple of tens of centimeters. It has not exceeded either the highest or the lowest allowable water level.

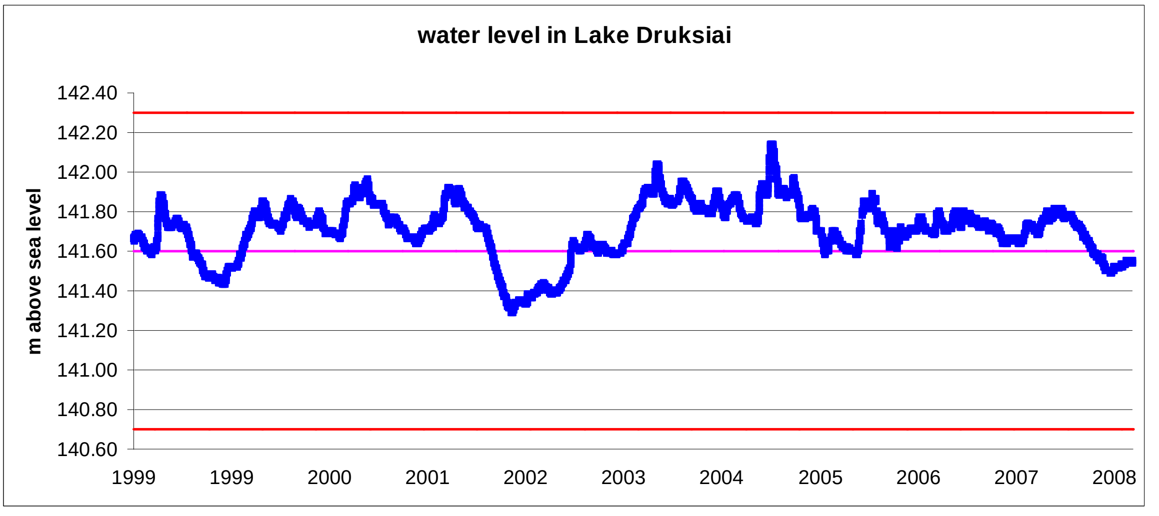


Figure 7.1-7. Water level in Lake Druksiai in years 1999–2008. The red lines indicate the maximum (142.3 m) and minimum (140.7 m) allowed water level. The pink line indicates mean water level (141.6 m).

The INPP is also monitoring the discharge to River Prorva. Discharges are calculated as a relation between water level and gate opening height based on a flow curve defined for the HPP (Figure 7.1-8).

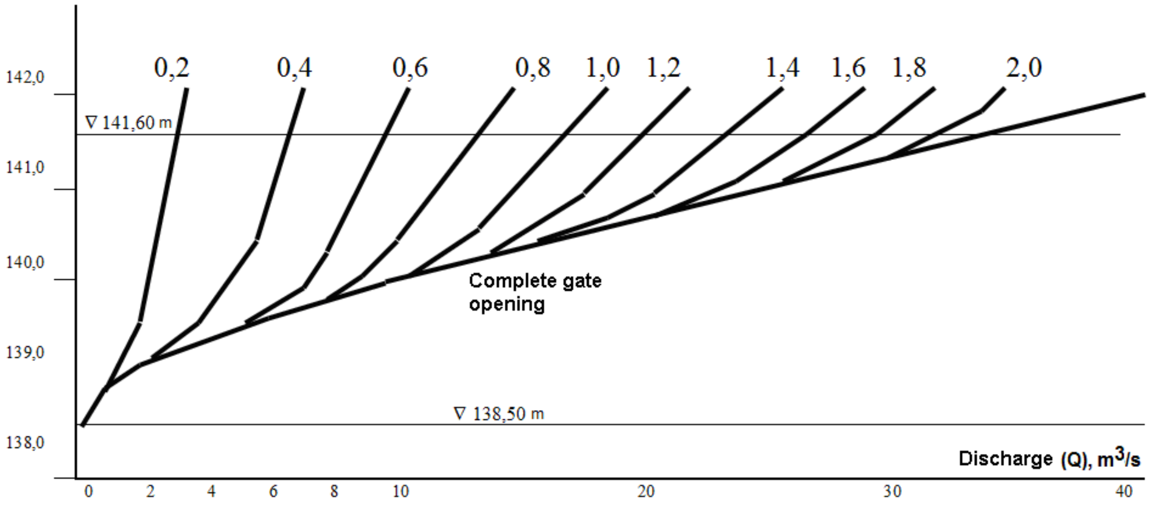


Figure 7.1-8. Dependence of water level, HPP gate opening height and the river flow.

According to these measurements the mean annual discharge (MQ) to River Prorva has been 4.4 m^3/s for the period of 1999–2008 (Figure 7.1-9). For the same period the mean high discharge (MHQ) has been 20.1 m^3/s and mean low discharge (MNQ) has been 1.4 m^3/s.

The calculated MQ is slightly higher than what has been estimated in the above chapter (7.1.1.3) by water balance calculations. However, the results can be considered analogous taking into account the fact that the calculation period is different and variation in the MQ does vary quite significantly between years depending on the weather conditions.

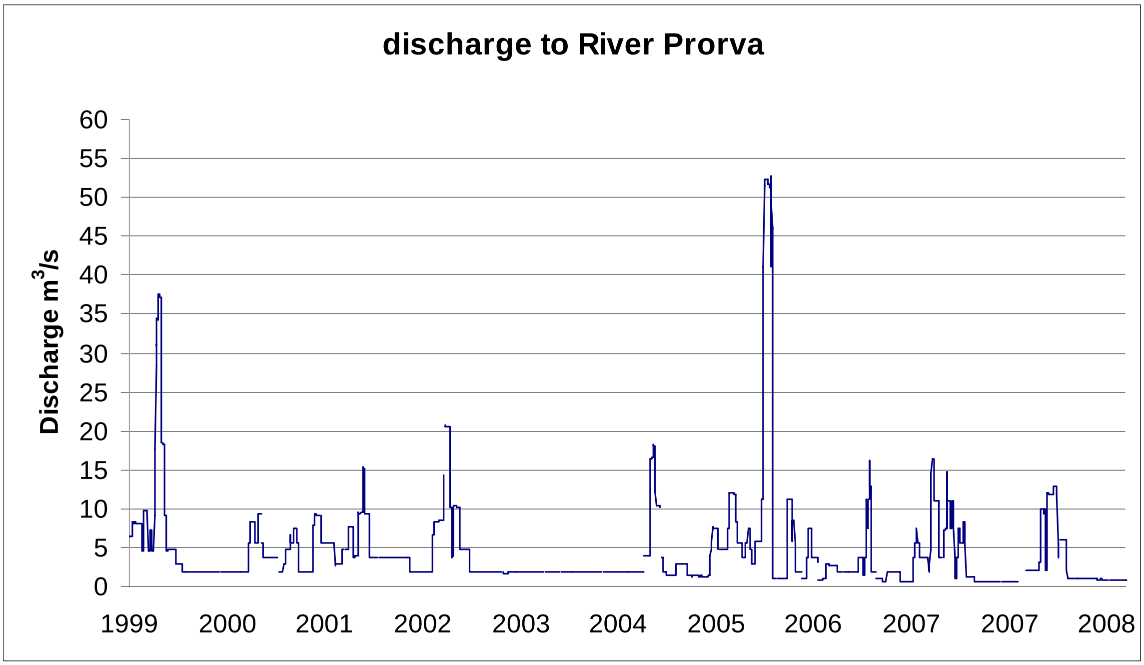


Figure 7.1-9. The discharge to river Prorva for years 1999–2008.

7.1.1.5 Aquatic ecosystem of Lake Druksiai

Several significantly different stages of ecological change in Lake Druksiai, due to the anthropogenic impact, can be distinguished. The first stage began immediately after the construction of the Ignalina NPP started. During that time large amounts of nutrients entered the water together with terrigenic materials (coming from the soil after works, from erosion phenomena, etc.), activating markedly the growth of autochthonous cryophilic (preferring or growing best at low temperatures) algae and cyanobacteria and increasing the activity of primary producers. This, in its turn, affected the organisms of other trophic levels. Even so, Lake Druksiai was classified as low productivity mezotrophic type of lake according to the mean annual values of primary production (25 g C/m^2).

The second stage of ecological change began after the first unit started operating in 1984. The heated water activated the processes, which continued to modify the structure and functional relations of organism communities. The destabilisation of the natural environmental conditions in the lake caused a decrease in the diversity of plankton organisms. The seasonal changes in quantity and biomass became very pronounced. Only 19 % of the phytoplankton species remained in comparison with the pre-operational period. Evidently dominating species composition had been changing. Accordingly, the primary production of organic substances was reduced 5-10-fold. A pronounced change in the diversity of plankton was recorded – their number and biomass were reduced 2.6-fold. It was noted that species of eurytermic organisms adapted themselves more easily to the new unstable conditions and their numbers increased. The abundance of cold-water species decreased.

The third stage of the change of the ecosystem started when the second unit was brought into operation in 1987, which was followed by a period of stable operation of the plant. New conditions developed and stabilised in Lake Druksiai ecosystem. The diversity of plankton organisms began to be restored. However, species more tolerant to increased temperature dominated. Their numbers and biomass and the primary production, particularly during the warm season, now resemble what is seen in eutrophic water bodies.

Water quality based on physicochemical parameters and bioindicators

The most intensive hydrochemical monitoring of Lake Druksiai was carried out between 1979 and 1997. The measurements were made at several sampling points all over the lake (Figure 7.1-10). More recent results (1999-2006) are available from reports on occasionally made investigations and from the monitoring programmes performed by INPP and EPA.

The main pollution source of Lake Druksiai is the household waste water load from the INPP and Visaginas town. The lake receives treated waste water used for household needs in the town and the INPP and untreated water from Visaginas and INPP rainwater sewers. The rainwater from the outbuildings of the INPP (8×10^6 m^3/year) and drainage water (1.5×10^6 m^3/year) extracted in order to keep the groundwater level of the INPP site low enough are led into a rainwater sewer and discharged to Lake Druksiai.

The wastewater treatment plant is designed for biological treatment and complementary cleaning with sand filters. The treated waste water is discharged into Lake Druksiai through the pond of additional purification (Lake Skripku) (tertiary treatment). However, Lake Skripku can nowadays be considered as a secondary source of organic pollution since the settled biomass or superior plants have not been removed and the accumulation of the produced biomass leads to a secondary eutrophication process. Around 5.5×10^6–8.5×10^6 m^3 of water enters Lake Druksiai annually from the wastewater treatment plant.

The INPP consumes about 365 tons of H_2SO_4 and 14 tons of NaOH per year for the regeneration of the resins loaded with strong acidic cationite and strong alkaline anionite, which are used to eliminate soluble salts from the water for the circulation circuits. The spent reagents neutralise one another in a specific tank (pH brought to between 6 and 9). After neutralisation, they are discharged into the rain sewerage system of the site, together with dissolved salts (SO_4^{2-}, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, etc.) (*Almenas et al., 1998*).

Other anthropogenic activities affecting the water quality in Lake Druksiai include the discharge of organic components from agricultural facilities and agricultural fields (fertilizers, soil particles, etc.). These are, however, considered less significant.

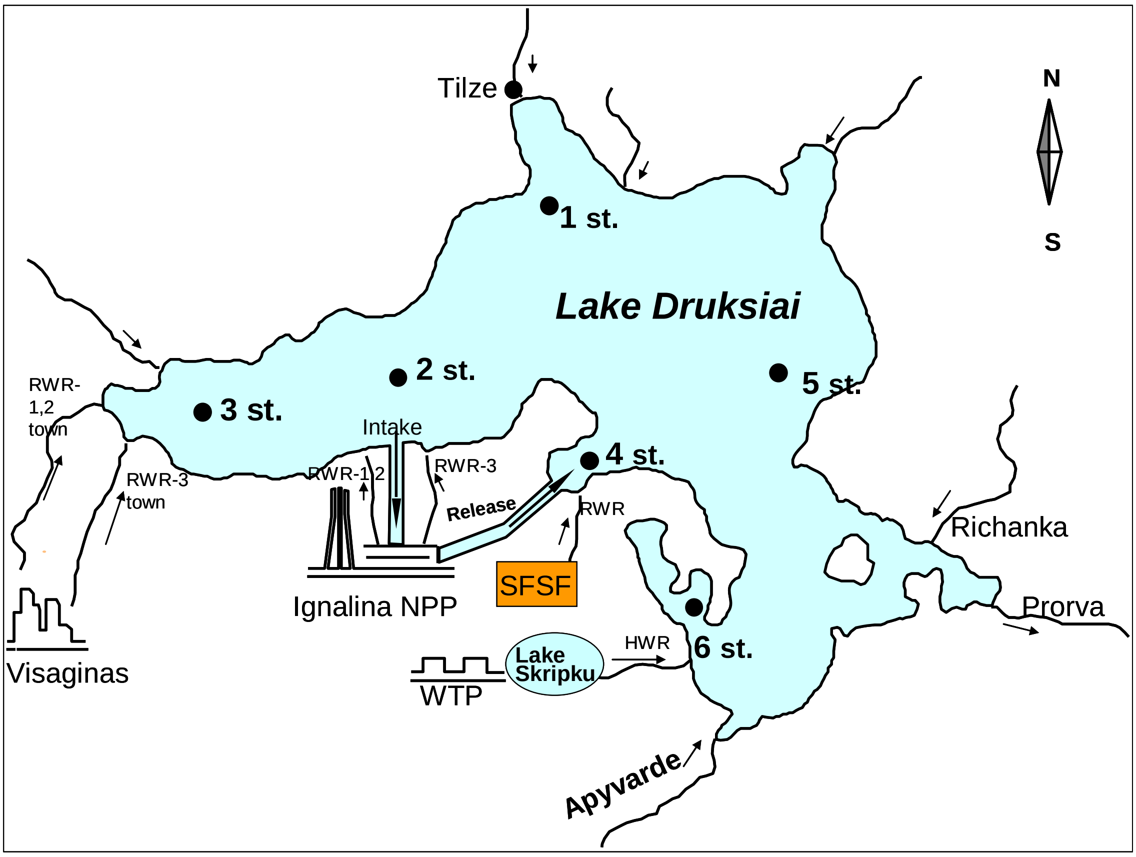


Figure 7.1-10. Permanent sampling station locations (1–6 st.; commonly used for the hydroecological investigations 1979–1997) and main inputs of cooling and waste waters in Lake Druksiai. RWR – rain water release, Intake – cooling water intake, Release – cooling water release, WTP – Wastewater treatment plant of effluents of INPP and Visaginas, HWR– household waste water release after biological treatment and pond (Lake Skripku) of additional purification, SFSF – Spent Fuel Storage Facility.

It can be concluded that the household waste water discharges from Visaginas and the INPP are major contributors of nutrients into the lake. This eutrophication has caused the major changes observed in the aquatic ecosystem of Lake Druksiai. Up to 1000 tons of organic carbon, 700 tons of nitrogen and 50 tons of phosphorus has been entering the lake annually with maximum values before the year 1991 (*Assessment of incoming…, 1991*). It was evaluated that mean annual concentrations of nitrogen and phosphorus in treated effluents even after the pond of additional purification (Lake Skripku) at that time were 37.7 mg N/l and 3.5 mg P/l accordingly. These figures considerably decreased in the last few decades due to improvement of the purification facility of household effluent (Figure 7.1-11). Still this source supplies ca. 55 % of nitrogen and 80 % of phosphorus of total annual amount to the lake (Table 7.1–4) (*Research Study…, 2008*).

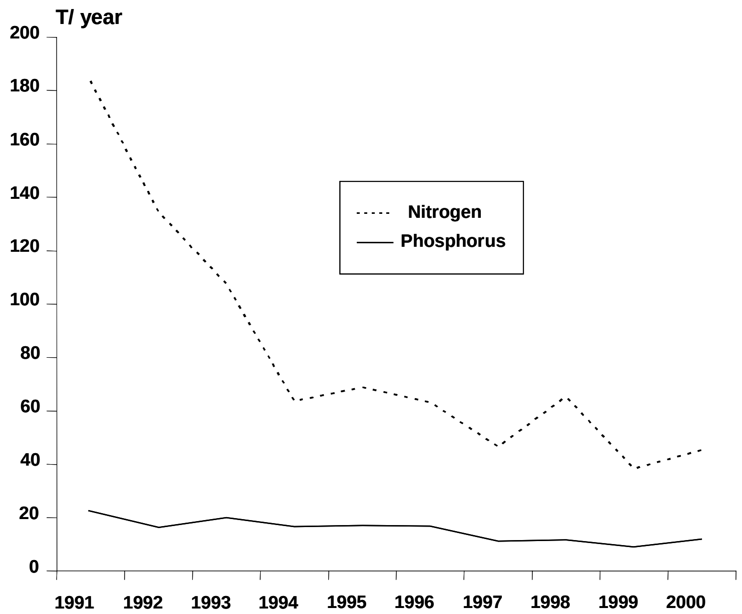


Figure 7.1-11. Nitrogen and phosphorus load into Lake Druksiai.

Table 7.1–4. Long-term balance (1991-2000) of nutrient load to Lake Druksiai.

Sources	N_t, t (N) year $^{-1}$	P_t, t (P) year $^{-1}$
Domestic and urban runoff	**85.53**	**15.291**
rainwater drainage of INPP site (RWR-1,2)	1.663	0.244
rainwater drainage of INPP site (RWR-3)	0.335	0.081
treated household effluents of INPP and Visaginas	81.625	14.720
rainwater drainage of Visaginas town (RWR-2 town)	0.617	0.046
rainwater drainage of Visaginas town (RWR-1 town)	0.416	0.04
rainwater drainage of site of spent nuclear fuel storage facility (RWR –SNSF)	0.870	0.16
Natural runoff	**62.02**	**3.88**
Total input	**147.54**	**19.17**
Prorva (output)	**98**	**14.11**

In addition, the thermal pollution which began in 1984 accelerated the processes of eutrophication. Heated water discharge led to changes in the hydrological conditions of the lake. The surface temperatures increased, the natural vertical thermal stratification was altered and the fast temperature and water usage changes due to unstable operation of the INPP led to acceleration of the hydrodynamic processes. Also, evaporation rates increased.

The increased temperature of the lake and the subsequent decrease of the cold water volume (see Figure 7.1-12 and Table 7.1–4) did not only stimulate the acceleration of eutrophication of the lake but also changed the prevailing conditions unfavourably for organisms able to live only within a narrow low temperature range (stenothermal cryophilic species). However, Lake Druksiai was still classified as low productivity mezotrophic type of lake according to the mean annual values of primary production (25 g C/m^2) (*Research Study…, 2008*) (Figure 7.1-13).

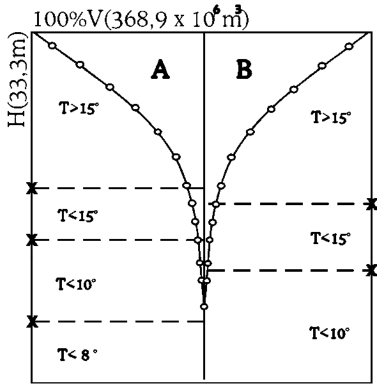


Figure 7.1-12. The distribution of thermic zones during summer stratification in Lake Druksiai, 1977–1983 – A and 1984–1997 m. – B (*Lithuanian State Scientific ..., 1998*).

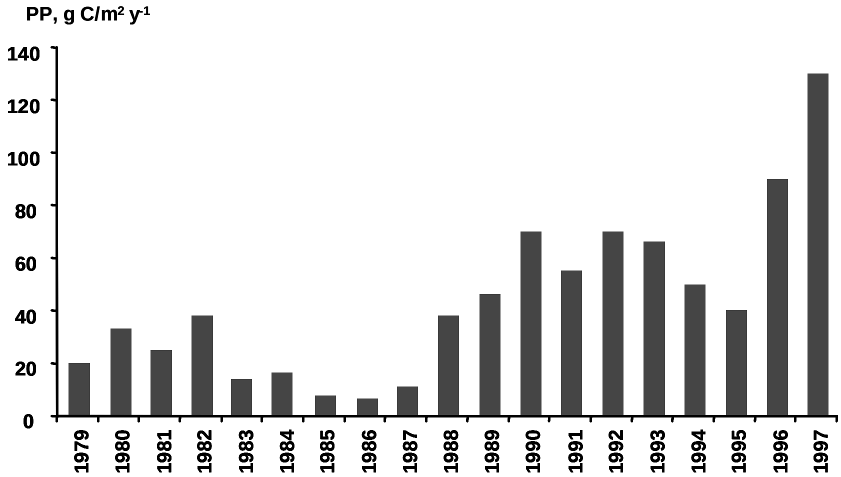


Figure 7.1-13. Mean annual values of primary production (PP, g C/m^2y^{-1}) in Lake Druksiai.

Increased sedimentation of terrigenic materials and organic substances (from 0.5 kg/m^2 in 1979 to 2.9 kg/m^2 per year in 1983) particularly in the deep water areas of the lake led to a fast accumulation of organic matter and nutrients into the bottom sediments. Concentration of dissolved organic material (DOC) has increased since 1979–1983 from 14 mg/l up to 19 mg/l in 2004. Also, increase in particulate organic matter (POC) has been observed in the bottom sediment of the lake.

Due to high activity of micro-organisms a decrease of dissolved oxygen content was also observed, particularly during summer periods and at a depth of below 12 m (Table 7.1–5).Recently the oxygen concentration has fallen below 4 mg/l already at 10 m, i.e. in the upper metalimnion. Oxygen depletion and some products of the terminal anaerobic processes produced unfavourable conditions especially to the cryophilic fish fauna inhabiting the deep layers of the lake.

Table 7.1–5. Distribution of oxygen in Lake Druksiai.

Depth, m	August 1983	August 2007
	O_2, mg/l	
0	8.5	8.64
6	-	8.32
10	6.9	3.84
12	3.3	3.52

Depth, m	August 1983	August 2007
	O_2, mg/l	
14	0.6	1.44
16	0.4	0.64
18	0.1	-
20	0	0.34
30	0	0

Due to the complex (thermal and chemical) anthropogenic impact the following ecological zones have developed in Lake Druksiai (Figure 7.1-14)**:**

- **Zone A**: The most eutrophicated south-eastern part of the lake, where the main source of eutrophication is the household effluents of the INPP and Visaginas with an elevated amount of nutrients (N, P). Increased amount of plankton as well as enhanced activity of production-decomposition processes are observed in this area. BOD_5 reached sometimes 12.5 mg O_2/l in this most polluted area;
- **Zone B**: The cooling water outflow zone is the area of the greatest thermal impact, where water temperature in many cases exceeds 28°C. The lowest abundance and variety of most planktonic organisms (phytoplankton and zooplankton) as well as lower rates of primary production and more intensive decomposition processes of organic matter are observed in this area;
- **Zone C**: The rest of the lake, including the deep and mediate deep zones, where the various impact factors affect the ecosystem occasionally, depending on the INPP operation, wind direction, waves, etc.

Table 7.1–6. Range of fluctuations of some parameters in different zones of Lake Druksiai, July–August 1993–1997 (*Research Study…, 2008*).

Parameter	Zone A	Zone B	Zone C
Secchi depth, m	1.0–2.8	3.0–3.9	1.2–6.5
Chlorophyll a, µg/l	6.6–113.5	0.88–16.5	0.99–70.0
Zooplankton biomass, mg/m^3	2 046–7 180	431–1 863	596–1 153
Phytoplankton primary production, mg C/m^3 d^{-1}	330–2 800	44–440	2–1 500
$C_{org.}$ total in bottom sediments, %	11.7–12.4	3.5–3.7	7.6–12.6
Organic matter mineralization in bottom sediments, mg C/m^2 d^{-1}	1 127–1 590	915–939	513–720

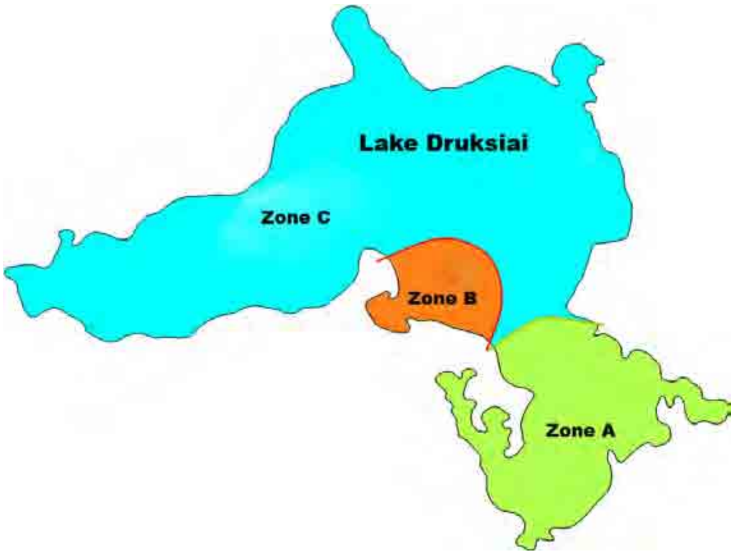


Figure 7.1-14. Distribution of different ecological zones in Lake Druksiai (1997).

During the last 20 years, from the pre-starting period of INPP operation, Lake Druksiai has changed from a mesotrophic lake (with medium concentration of nutrients and biological production) to a eutrophic lake (with elevated concentration of nutrients and biological production). The most obvious evidence of eutrophication has been the evolution of the N_{total}/P_{total} annual average weight ratio from 21:1 (1983) to 8:1 (1997) (*Salickaitė-Bunikienė, Kirkutytė, 2003*). It can be concluded that this has stimulated the changes observed in the plankton community, since reduction of the N/P ratio to values of 5-10 can lead to a community dominated by *Cyanophyta* (*Bulgakov, Levich, 1999*). Until recently the N/P ratio has fluctuated at the same low level or has had a slight tendency to increase (Figure 7.1-15).

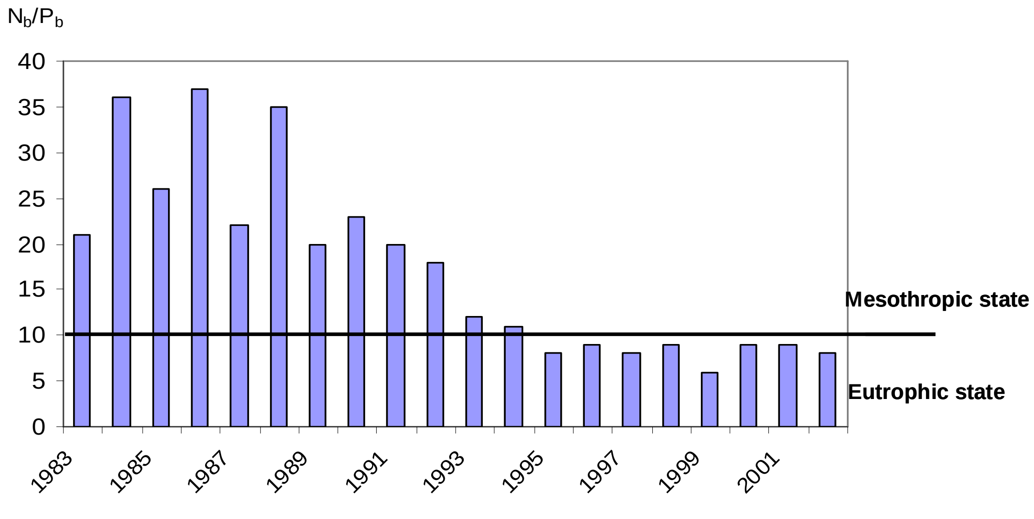


Figure 7.1-15. Mean annual values of N_{total}/P_{total} weight ratio in Lake Druksiai.

After the beginning of INPP operation (1984–1988) mean annual concentration of N_{total} in the water of Lake Druksiai has increased up to 1.53 mg N/l in comparison with that of the prestarting period (1.29 mg N/l) (Table 7.1–7). Later on immobilization and export of organic matter as well as high activity of denitrifying micro organisms in bottom sediments have reduced the amount achievable for other organisms. It has been evaluated that losses of nitrogen due to denitrification reaches 40 % of the total load (*Assessment of incoming…, 1991*).

Table 7.1–7. Long-term annual mean values of the nutrient concentrations in Lake Druksiai (*Research Study…, 2008*).

Parameters	Periods					
	1979–1983	1984–1988	1989–1993	1994–1997	1998–2002	2001–2006
N-NH_4^+, mg/l	0.22	0.35	0.21	0.20	0.29	0.058
N-NO_x^-, mg/l	0.051	0.062	0.072	0.083	0.054	0.05
N_{total}, mg/l	1.29	1.53	1.14	1.26	1.55	0.93
$P_{min.}$, mg/l	0.007	0.012	0.023	0.025	0.028	0.031
P_{total}, mg/l	0.061	0.05	0.072	0.146	0.179	0.058

At the end of last century the annual average concentration of N_{total} had an even higher range and reached 1.55 mg N/l. According to the data of EPA, at present the annual average nitrogen concentration has a lower range and varies between 1.028 and 0.863 mg N/l (*http://aaa.am.lt/VI/index.php#r/1696*).

Contrary to nitrogen, concentration of phosphorus, both mineral and total concentrations have been increasing almost throughout all the investigation time in Lake Druksiai (Table 7.1–7). Average concentration of phosphates still has tendencies to increase, although total phosphorus (according to EPA data) decreased significantly. This in turn should indicate a tendency of improvement of the environmental conditions in Lake Druksiai.

A slightly increasing tendency of total dissolved salts in the water has been observed recently. Waters of Lake Druksiai are dominantly bicarbonate-calcium with medium total dissolved solids (TDS) content. Evaporation from the surface of a lake was expected to become the most important push to increase the concentration of salts in the remaining water (*Dryzius et al., 1984*). However, it did not have a noticeable effect during several decades of operation of the INPP mainly due to the decrease of HCO_3^- and Ca_2^+ concentration despite the fact that the content of chlorides, sodium, potassium, sulphates, magnesium increased (Table 7.1–8) (*Research Study…, 2008*).

Table 7.1–8. Average long-term main ion concentrations and TDS (Σj) values in Lake Druksiai.

Parameters	Periods				
	1979–1983	1984–1988	1989–1993	1994–1997	2001–2006
Cl^-,mg/l	8.8	9.9	10.7	9.8	12.9
SO_4^{2-}, mg/l	8.9	12.6	18.6	19.3	18.0
HCO_3^-, mg/l	160.5	150.4	157.6	159.4	169.5
Ca^{2+}, mg/l	39.3	35.8	36.8	35.8	37.9
Mg^{2+}, mg/l	10.0	10.9	12.9	13.8	15.9
Na^+, mg/l	4.6	6.3	7.0	6.9	7.5
K^+, mg/l	1.8	2.7	3.0	2.9	3.2
TDS, mg/l	233.9	228.6	246.6	247.9	264.3

It is assumed that fast mass development of alien zebra mussels and aquatic vegetation has led to the decrease of Ca^{2+} and HCO_3^- concentrations at the beginning of INPP operation (*Research Study…, 2008*). Minimal values of TDS were observed in 1985 (Figure 7.1-16).

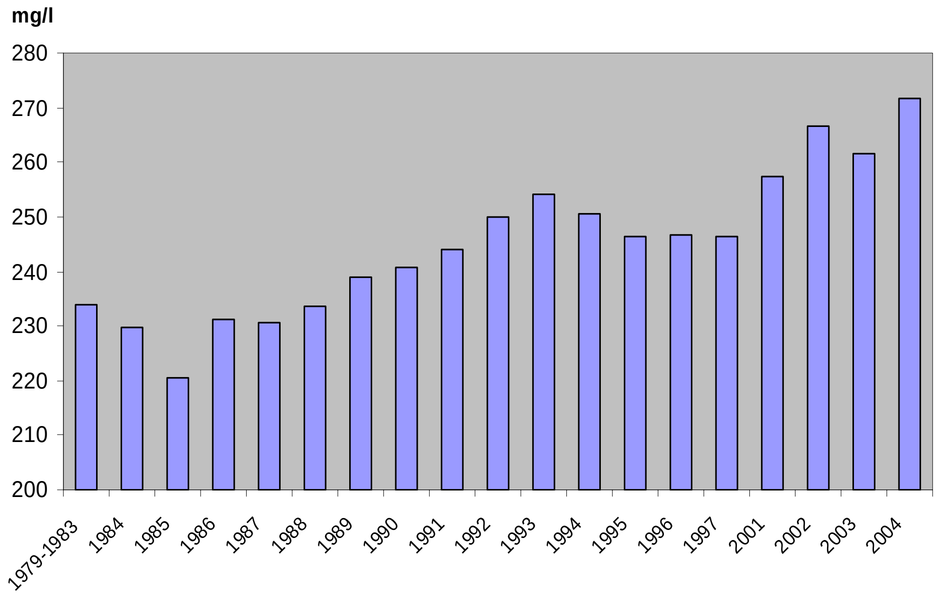


Figure 7.1-16. Long-term TDS values in Lake Druksiai (1979–1997 – average for the whole lake, 2001–2004 measurements were made only in the western part of the lake).

One of the most evident changes that has happened during the operation of the INPP is the quite fast increase of sulphates in the lake water and bottom sediments. The main sources of these sulphur compounds are the discharges of spent reagents (H_2SO_4 and NaOH) into the rain sewerage system after regeneration and neutralization processes. This has led to intensification of microbial sulphate reduction in bottom sediments very fast, eliminating the other terminal process methanogenesis. Therefore, in the pre-start-up and commissioning periods of the first unit hydrogen sulphide was already observed in the bottom sediments in the closest vicinity of the INPP. The highest rate of sulphate reduction (up to 3.8–4.3 mg $S^{2-}/dm^3\ d^{-1}$) was observed in 1992. Later on the intensity of the processes decreased but it continues to remain relatively high in some parts of the lake (Figure 7.1-17). In combination with oxygen depletion it can harmfully influence the living conditions of the fauna inhabiting these water layers.

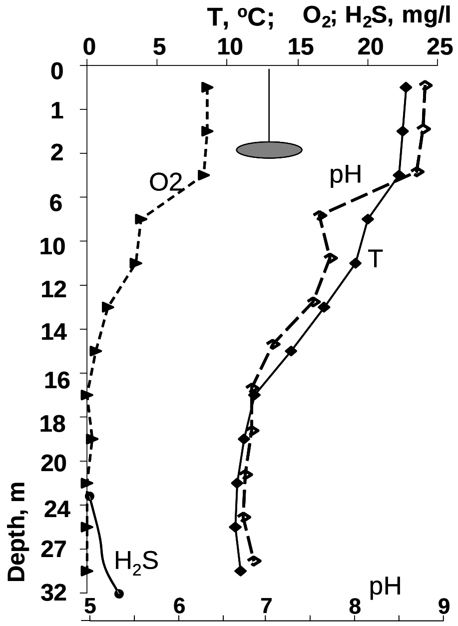


Figure 7.1-17. Vertical distribution of physical-chemical parameters in Lake Druksiai during maximal midsummer stratification, August, 2007 (standard station No. 1).

Direct contamination of Lake Druksiai emanate from the industrial areas and the town via the rain water release systems, supplying the lake ecosystem with many contaminants and inhibitors of biological processes. However, the concentration of copper, lead, chrome, cadmium and nickel has not exceeded the allowable values for water quality, except that manganese reached 47 µg/l (5 times the maximum allowable value) (*EPA Annual report, 2003, http://aaa.am.lt/VI/index.php#r/1696*). It has been estimated that heavy metal contaminated sediments (from intermediate to high level of contamination) cover 27.5 % of the lake bottom area but the major part of this has a natural origin since the natural hydrocarbons dominate. Pollution with oil products was identified in 3.9 % of the bottom area (*Lithuanian state scientific …, 1998*).

In conclusion, eutrophication, the increase of salts content and warming of the lake water interact to influence the habitats and ecosystems of the lake. Despite these changes in the lake ecosystem, the parameters examined still meet the requirements and range within the limit (imperative or guide) values set up by Directive 2006/44/EC and by the LR legal act „Description of Requirements for Protection of Surface Water Bodies where Freshwater Fish Can Inhabit and Reproduce“ (*State Journal, 2006, No. 5-159*).

This lake was in a very good condition (pursuant to the research data of 2005–2006) with regards to chlorophyll “a” and in a good condition with regards to total nitrogen and total phosphorus. Nevertheless, negative changes have been observed – the average condition with regards to total phosphorus in the near-bottom is an indicator of negative impact. Estimations of the composition and state of the fish community only confirm that the condition of the lake turns for the worse. As the temperature of the water had been increasing the fish variety and the structure of its communities changed correspondingly. The abundance and biomass of psychrophilic fish decreased significantly, although the lake is characterised by a quite high productivity of the ichthyofauna. Recently about 18 fish species have been caught in Lake Druksiai. The basic part of the biomass of the ichthyofauna is constituted of 10 fish species: Roach, perch, silvery bream, carp bream, vendace, bleak, rudd, ruff, pike and tench. In the lake commercial fishing and quite intense recreational fishing is carried out, and therefore the fish resources could have decreased. Also algae blooms are observed more often. The reduced water transparency in summer suggests that Lake Druksiai changes towards the euthrophic state faster than it should. This state would be reached simply during natural aging of the lake, but now this process can be accelerated several times (*http://aaa.am.lt/VI/index.php#r/1696*).

Phytoplankton and zooplankton communities in Lake Druksiai

Most of the investigations concerning planktonic organism communities were performed from 1979 to 1997. Tendencies of the changes in different ecological zones were evaluated in 1993-1997 *(Lithuanian State Scientific ..., 1998).* Since 2001 phytoplankton has been monitored by Lithuanian Environmental protection agency (*http://aaa.am.lt/VI/index.php#r/1696*). In accordance with the State environmental monitoring program only one sampling site was determined in Lake Druksiai in its western part. Due to reduced sampling sites and collecting frequency, data of recent years are scarce and sometimes controversial.

It can be stated that the main impacts that have modified the plankton communities are the thermal releases from the INPP and household waste water or wastes from other activities. The increase in the temperature of the lake and the subsequent decrease of cold-water volume led to changes in species composition. Since 1984 the amount of the prevailing plankton species decreased 2 to 3 fold in comparison with INPP pre-operation: phytoplankton – from 116 to 40–50, metazoo- and protozooplankton – from 118 to 38 and taxa from 129 to 45–53. Phytoplankton dominants from the pre-starting period of the INPP (cyanobacteria *Limnothrix redekei* (Van Goor) Meffert, *Planktothrix agardhii* (Gomont) *Anag.* and *Komar.* and some diatom species) and zooplankton species (e.g. *Limnocalanus macrurus Sars*, relic from glacial period) have disappeared.

The diversity of phytoplankton has decreased and the abundance of the few dominant species has increased in the lake. This can lead to a phenomenon where colonies of one single species (e.g. *Stephanodiscus binderanus* (Kütz.) in March 1992) may become almost monodominant in plankton community. These diatom species have cells surrounded with bulk mucilage during the resting stage of the development. They can hinder the plant operation by accumulating at the cooling water supplying system. In Lake Druksiai this has happened several times in the early nineties during the vernal phytoplankton blooms. Several potentially toxic cyanobacteria species (from genus *Anabaena, Aphanizomenon, Gloeotrichia, Microcystis*) have also been identified. The mass development has been occasionally observed in Lake Druksiai during the midsummer phytoplankton blooms.

The abundance and biomass of phytoplankton have varied significantly during the years 1979-2006 and no clear trend can be observed. However, the biomass of phytoplankton dropped from 2.6 mg/l in 1984 to 0.2 mg/l in 1988 (Figure 7.1-18). It has become more abundant later on performing high variability of development during different years. It could be attributed to instability of the working regime of the INPP within the year. New dominant species composition in phytoplankton community may or may not thrive in randomly changing environmental conditions.

Changes in phytoplankton community in the different parts of the lake were studied during the years 1993–1996 (Figure 7.1-19). Despite high spatial and temporal variability in biomass density the most eutrophicated south-eastern zone has always been the most productive one. Even in this part the interannual variability of phytoplankton development has been quite evident and not necessarily always fluctuating in the manner as in the rest of the lake. In addition, the interannual variability of average concentration of chlorophyll *a* (from 2 to over 14 µg/l) also indicates instability in the ecosystem which has led to high spatial variety even in a highly eutrophicated water body. Therefore, it is not possible to evaluate the state and tendencies of changes of such a water body by means of occasionally performed investigation from one site, not taking into account the large variation between different sites.

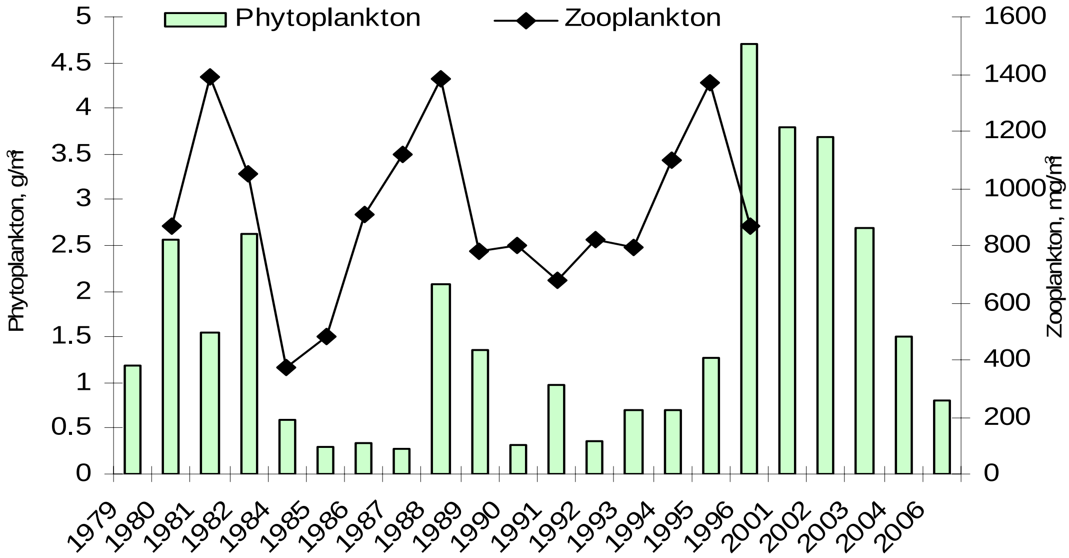


Figure 7.1-18. Interannual variability of yearly average phytoplankton (g/m^3) and zooplankton (mg/m^3) biomass in Lake Druksiai.

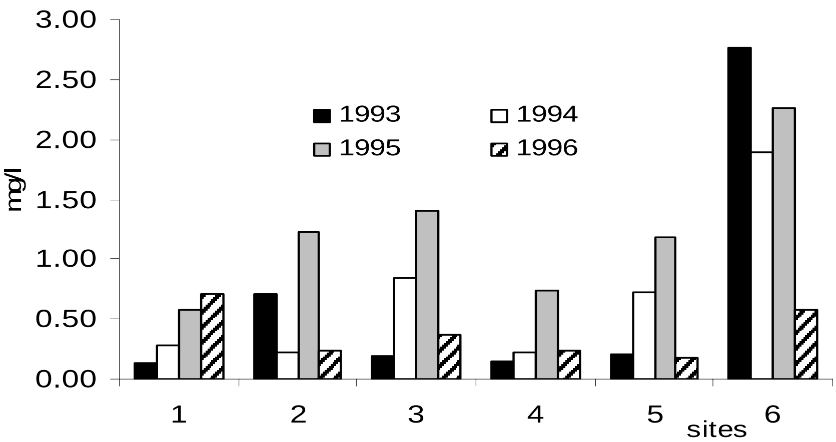


Figure 7.1-19. Interannual variability of yearly average phytoplankton biomass (mg/l) in the different sites of Lake Druksiai.

The abundance of metazooplankton decreased more than 2.7-fold (107.5 to 39.1 thousand ind./l) and protozooplankton halved (from 2.8 to 1.2 thousand ind./l) during the first two years of INPP operation (Figure 7.1-20). After a certain gap of low productivity and changes in dominant species composition in the community, a relatively short increase in zooplankton biomass was observed in Lake Druksiai from 1986 onwards when new conditions developed and stabilised in the ecosystem. At the same time, former numerous but less adaptive to fast changing conditions Rotatoria decreased more than 10-fold (Figure 7.1-20). Crustaceans and especially Cladocera increased significantly for a few years after the plant had started operation. After the year 1988 unstable conditions led to a constant fluctuation in the abundance, biomass and taxonomic variety of the zooplankton in Lake Druksiai.

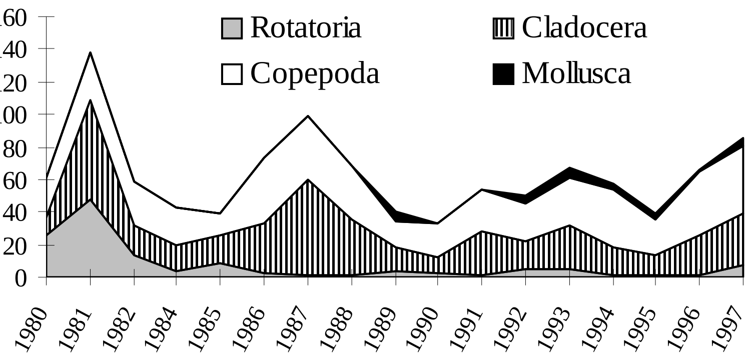


Figure 7.1-20. Interannual variability of yearly average metazooplankton groups abundance (thous.ind./m^3) in the deepest part of Lake Druksiai during 1980-1997 summer periods.

The INPP operation has obviously influenced the plankton community by stimulating temporal and spatial instability of the seasonal succession. Despite the fact that mean annual plankton biomass values have not increased permanently other phytoplankton parameters indicate unpredictable effects of the lake eutrophication. In addition to decreased species diversity, the mass occurrence of cyanophytes is always a signal of severe eutrophication of a lake. Intensity and frequency of the blooms have increased and are varying during the year. Until recently dominant species composition has not stabilized in Lake Druksiai. However, the species mostly characteristic of the eutrophic water bodies are dominating the plankton community.

Aquatic vegetation in Lake Druksiai

During the investigations of Lake Druksiai in 1996–1997 73 aquatic macrophyte species were recorded, among them eight *Charophyta*, two *Bryophyta*, one *Equisetophyta*, and 58 *Magnoliophyta* species.

Altogether 27 vegetation communities (associations) were found. Among them common reed (*Phragmitetum australis*) and common club rush (*Scirpetum lacustris*) communities were dominant in the zone of emerged plants from shore up to a depth of 1.5–2 m; communities of pondweeds (*Potamogetonetum lucentis Potamogetonetum perfoliati*, *Potamogetonetum mucronati*, *Potamogetonetum rutili)* are quite common in the zone at a depth of 1-5 m; community of starry stonewort (*Nitellopsidetum obtusae*) was dominant in the zone of completely submerged plants (limneids) at a depth of 3-5(7) m. Communities of march-grass (*Scolochloetum festucaceae*), smooth stonewort (*Nitelletum opacae*) and horned pondweed (*Zanichellietum palustris*), which are rare for Lithuanian water bodies, were found.

Before operation of the INPP (investigation period of 1979–1983) Lake Druksiai was characterized as a typical mesotrofic lake of moderate depth with well developed submerged vegetation (dominant species *Chara rudis, C. filiformis, Nitellopsis obtusa, Potamogeton lucens, P. perfoliatus*) and fragmentally developed floating leaved and emerged vegetation (*Potamogeton natans, Phragmites australis*). Maximum depth limit for vegetation varied from 7 to 9 metres.

At that time Lake Druksiai was a typical example of water bodies with dominant benthic vegetation of Charophytes. This habitat type is included in Annex I of EEC Habitats directive, as important for protection throughout Europe.

After 20 years of INPP operation significant changes were observed in all ecological zones of aquatic vegetation.

Charophyta species have totally become extinct from the submerged plant zone of shallow areas near the INPP (stations 4, 6 areas influenced by sewage and cooling waters) and only species tolerant to eutrophication (*Ceratophyllum demersum, Myriophyllum spicatum*) have survived.

The decline of Charophytes, especially the earlier dominant *Chara rudis* and *Chara filiformis* species, was observed in the limneid zone (zone of completely submerged vegetation) of the entire lake.

Depth limit for submerged vegetation decreased from 7–9 m to 5–6 m. The intensive development of filamentous green algae during a prolonged vegetation period and decrease of water transparency was an important reason for the decline of submerged vegetation (e.g. Charophytes) from the deepest locations. The areas occupied by helophyte communities (*Phragmites australis, Schoenoplectus lacustris*) increased significantly in shallow areas up to 2 m.

The observed changes in aquatic vegetation, first of all, extinction of *Charophyta* in the zones of obvious thermal and chemical impact and declining of those species in the whole lake is evident indication of increasing trophic state in the cooling reservoir of the INPP (*Blindow, 1992*). Spatial and seasonal fluctuation of turbidity and mass development of filamentous green algae were actual reasons of significant decreases in maximal depth limit of submerged vegetation. Simultaneously, mass development of helophytes in shallow coastal zones of the lake evidently indicates anthropogenic eutrophication.

Bottom fauna and other invertebrates in Lake Druksiai

In investigations on the basic state (1976–1983) of populations and communities of aquatic animals of Lake Druksiai 143 macrozoobenthos species were found, including *Spongia* – 1, *Coelenterata* – 3, *Turbellaria* – 2, *Nematomorpha* – 1, *Oligochaeta* – 37, *Hirudinea* – 7, *Mollusca* – 39, *Crustacea* – 10, *Insecta* – 43 (*Grigelis, 1986*). Dominating taxa were chironomides and oligochaetas and in the littoral and sublittoral zones also molluscs; especially *Dreissena polymorpha*, which settled in the lake during the period of the basic investigations. The dominating species in the littoral and sublittoral were *Stictochironomus psammophilus*, *Psammoryctides barbatus*, *Lumbriculus variegatus*, *Bithynia tentaculatae*, *Leptocerus cinerans*, and in the profundal – *Chironomus anthrecinus*, *P. hommoniensis*, *Chaoborus flavicans*, *Mysis oculata relicta*, *Pallasea quadrispinosa*. Also, several stenothermal (tolerate only a narrow range of temperatures) species were observed; *Ch. ahthracinus*, *S. longiventrus*, *P. amnicum* and glacial relicts *M. o. relicta* and *P. quadrispinosa*.

In the period of 1984–1986 (during the first year of INPP operation), the abundance of former bottom fauna communities (crustaceans and bivalve molluscs – unionids) has decreased. At the same time the number of worm-like organisms (oligocahetes) has increased (*Grigelis, 1993*). The crustaceous species which preferred a narrow range of low temperature and well oxygenated conditions (relicts of the glacial period) have been either completely eliminated or their quantity has significantly decreased.

Changes in the littoral communities have been due to the intensive development of the eurythermal mussel *Dreissena polymorpha* (zebra mussel), which spread to the lake during the period of INPP construction. Until the year 1981 it was observed in only low numbers. However, the juveniles dominated in 1982, and exhibited rapid growth rates during 1983–1984. Massive developments were observed in the meadows of Charophytes and reeds (*Phragmites*) communities. In 1985 the biomass of zebra mussels was 1300 tonnes (*Grigelis, 1993*). The highest biomass observed in 1989 reached 5 600 tonnes.

The biomass of zoobenthos, except that of *Dreissena polymorpha*, has remained unaltered from 1976 until today. Any signs of decrease in zoobenthos due to bottom erosion or redistribution of sediments by circulating currents have not been observed in Lake Druksiai.

Fish community in Lake Druksiai

In its basic state, Lake Druksiai was a typical mesotrophic lake, i.e. one of the early successive stages of Lithuanian lakes, according to the composition of fish community. During the construction and operation of Ignalina NPP the composition of fish community has altered (*Virbickas et al., 1993*).

According to the data from different sources, 23–26 fish species were recorded in the lake in the second half of last century. Before the beginning of the construction of the INPP (1950–1975), the fish community of Lake Druksiai was dominated by lake smelt and vendace, the biomass of which accounted for ca. 40 % of the total fish biomass of the lake. Also roach (*Rutilus rutilus L.*), perch (*Perca fluviatilis L.*), bream (*Abramis brama L.*) and pike (*Esox lucius L.*) were common. Lake Druksiai was also inhabited by alien species introduced from the neighbouring lakes through small streams, namely the Peipsi whitefish (*Coregonus lavaretus maraenoides Poljakow*), common carp (*Cyprinus carpio L.*) and later the pikeperch (*Sander lucioperca L.*) and sunbleak (*Leucaspius delineatus Heck.*), which became widespread all over Lithuania. It is also interesting to note that at that time the lake was home for rarer species – wels (*Silurus glanis L.*) and gudgeon (*Gobio gobio L.*). The littoral zone where rivers take their rise was even inhabited by typical river fishes: bullhead (*Cottus gobio L.*), dace (*Leuciscus leuciscus L.*) and ide (*Leuciscus idus L.*). High fish diversity, including the occurrence of stenothermal species, evidenced highly favourable ecological conditions for this group of fish.

The biomass of lake smelts started to decrease already in the period of construction of the power plant in 1976–1983, when considerable amounts of nutrients found their way from land to water and large zones with lack of oxygen formed in the near-bottom strata of deepwater areas. Particularly drastic decreases in the biomass of stenothermal fish were observed in the first years of operation of the INPP (1984–1986): the total biomass decreased 8-fold, of lake smelts 2.7-fold, and of vendaces even 58.8-fold. In the meanwhile, the total biomass of eurythermal fish species went up by ca. 35 %, though the total biomass of fish community increased by merely 2.5 %. After launching the second reactor unit (1987–1988), the total biomass of fish increased by 14.2 % compared to 1976–1983 (*Research Study…, 2008*).

The population of vendace decreased 28.9-fold during the NPP construction, from 2.31 million in 1979 to 0.08 million individuals in 1981. In the following years abundance of vendace was very low and partial recovery of the population was observed only starting from 1991. The abundance fluctuated insignificantly during the period of 1993–1997 (Table 7.1–9).

Table 7.1–9. Abundance of pelagic fishes in Lake Druksiai according to hydroacoustic study, verified by gillnetting (millions of individuals).

	1979	1981	1983	1985	1986	1991	1992	1993	1994	1995	1996	1997
Lake smelt	25.47	60.78	19.02	5.12	1.12	0.14	0.04	0.02	0.03	0.028	0.027	0.03
Bleak	24.31	12.62	13.2	5.85	2.38	0.79	2.62	4.5	6.2	2.8	3.37	9.85
Perch	0.58	0.96	1.62	1.75	2.99	1.66	7.44	8.9	9.3	7.8	6.94	7.46
Roach	2.59	4.18	3.73	3.19	1.38	1.76	5.41	5.5	7	6.6	5.14	4.43
Vendace	2.31	0.08	0.04	0.08	0.09	0.27	1.2	3.2	3.3	2.3	2.76	2.74

	1979	1981	1983	1985	1986	1991	1992	1993	1994	1995	1996	1997
Ruffe	0.29	1.04	0.16	0.25	0.03	0.37	1.31	2.4	2.3	1.8	1.49	1.06
Silver bream	0.05	0.08	0.15	0.17	0.01	0.4	2.1	2	3.4	1.9	1.37	1.29
Bream	0.39	0.48	0.46	0.34	0.48	0.41	1.03	0.8	1.2	0.5	1.32	0.18

Abundance of smelt amounted to 60.8 million individuals in 1981. Later its population decreased to 1.1 million individuals in 1986 and during the period from 1993 to 1997 the population remained very sparse in number. Physiologically optimal temperature for smelt during the summer thermal stagnation is 12°C which is lower than the optimal temperature for vendace. Sharp decrease of smelt abundance could also be attributed to deteriorated oxygen regime in the near-bottom layers, increased rate of sedimentation, and emergence of epizootic sources.

Since the beginning of INPP construction and following its initial operation, the amount of eurythermal and thermophylous fish species constantly increased as well as their relative biomass in the fish community. Notable increase in numbers of perch was observed in the pelagic zone of the lake. Its amount increased from 0.6 million ind. in 1979 to 7.4 million in 1992. Abundance of perch during 1993–1997 remained at high levels and fluctuated insignificantly.

Species composition in the pelagic zone of Lake Druksiai did not change notably during 1992–1997. Eurythermal fish species such as roach, perch, bleak and silver bream (*Blicca bjoerkna L.*) were dominant amounting to 35.5, 20.0, 11.2 and 8.8 % respectively in the total fish biomass. Relative biomass of vendace decreased to 5.5 %, while the amount of smelt in the total biomass dropped even lower to 0.001 %.

No significant fluctuations in the biomass of most fish species were recorded in 1994–1999. The fish biomass of the lake was mainly composed of the populations of 10 species: roach, perch, silver bream, bream, bleak, rudd (*Scardinius erythrophthalmus L.*), gudgeon (*Gymnocephalus cernuua L.*), pike and tench (*Tinca tinca L.*). In total, 18 fish species have been registered in the lake during the investigation period.

Investigations into the change of reproductive indices of fish were carried out in Lake Druksiai in the first years of operation of the INPP (*Virbickas et al., 1993*). However, subsequent investigations in the lake focused merely on changes in fish numbers and biomass in the pelagial of the lake; therefore, they could not give a complete view of qualitative and quantitative changes in the fish community. Investigations into the structure and growth rates of different age groups of the vendace of Lake Druksiai after the INPP started operation showed that their growth rates changed significantly because of change of ecological conditions in the lake (*Research Study…, 2008*).

Roach was a predominant species in both littoral zones of different temperatures in Lake Druksiai. In the 'cold' zone it constituted 41.4 % of the total number of fish, amounting to 50.7 % of the total fish biomass. In the 'warm' zone these numbers were 46.6 and 34.3 % respectively. High abundance of perch and silver bream populations was observed in the littoral zone. Perch amounted to 23 % of fish number in both zones, whereas silver bream constituted 28.9 % and 11 % in the 'cold' and 'warm' zones accordingly. Relative abundance of roach amounted to 17.5 % in the 'warm' zone of the littoral. Relative biomass of the species reached 32.0 %. However, in the 'cold' littoral zone its share was low, constituting 1.7 % in number and 1.7 % of the total biomass. Other fish species in the littoral zone were characterized by low levels of abundance and biomass.

Studies on fish community in different aquatic areas of Lake Druksiai in 2005–2007 revealed significant changes in species diversity and community structure caused by changes in thermal regime and intensive anthropogenic eutrophication.

The species diversity in Lake Druksiai decreased from 23–26 fish species (before INPP operation) to the current list of 14 species. The lake is no longer home to the lake smelt, wels and some introduced species such as the whitefish and pikeperch. The littoral of the lake does not hold river fish species such as the bullhead, dace, ide nor gudgeon, a recent dweller of the littoral. The numbers and distribution of the tench and introduced warm-water species such as the gibel carp and common carp increased; catches of the grass carp and silver carp are also recorded. The list of fish community was composed of typical, most frequent dwellers of such type lakes: vendace, pike, roach, bream, silver bream, tench, bleak, rudd, crucian carp, common carp, spined loach, burbot, ruffe and perch. Among those, 2 fish species are from the list of protected species in the EU Habitat Directive: spined loach, which is a rather frequent species dwelling exclusively in the shallow part of the lake, and vendace, which, contrary to the spine loach, is habiting the deepwater zone of the lake and is a pelagic coldwater fish.

Considerable changes can be observed in the fish community structure as a result of thermal regime changes and impact of intensive anthropogenic eutrophication. The structure of the fish community from years 2005–2007 (density (N, %) and biomass (B, %) per CPUE (catch per unit effort) in Lake Druksiai is presented in Figure 7.1-21.

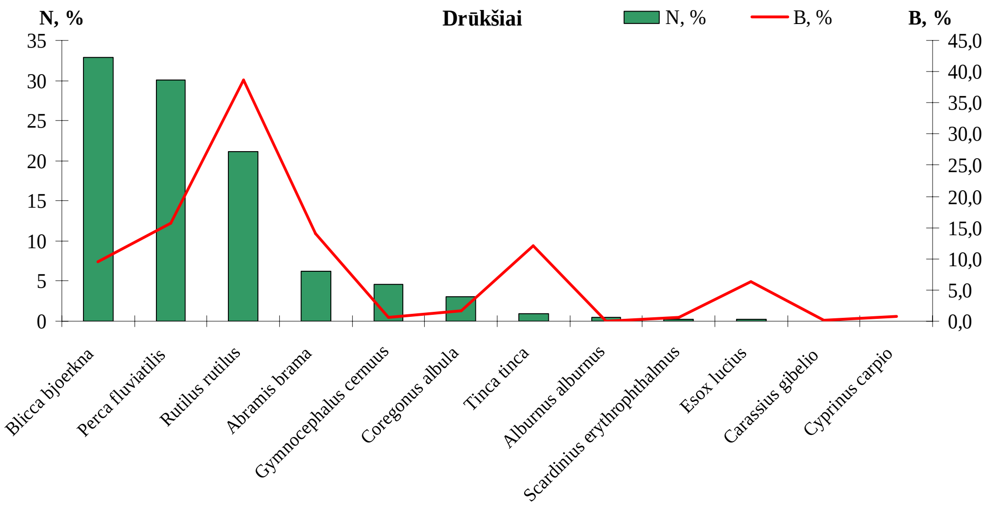


Figure 7.1-21. Fish community structure by density (N, %) and biomass (B, %) per CPUE (30 m length net) in Lake Druksiai in 2005–2007.

Lake Druksiai has undergone a change of dominant species. The fish community is composed mainly of 3 eurythermal species: silver bream (32.9 %), perch (30.1 %) and roach (21.7 %). Recently the abundance of silver breams particularly increased whereas the numbers of the roach and bream decreased accordingly. The populations of stenothermal species decreased to the critical level: the lake smelt is not caught at all and the vendace accounts for merely ca. 3 % of the total number of fish. By biomass, the lake is dominated by the roach (38.7 %) followed by several species with insignificant variations in biomass: perch (15.7 %), bream (14.0 %), tench (12.1 %) and silver bream (9.5 %).

The results of the monitoring of 2007 have revealed differences in abundance and biomass of fish between different sites in Lake Druksiai. In the “warm water” zone, fish abundance in summer and autumn was higher than in the “cold water” zone and reached 61.4 individuals per CPUE, whereas in the “cold water” zone, abundance averaged merely 25.1 individuals. As regards biomass per CPUE, the situation was the opposite, i.e. 59.96 kg in the "cold water" zone against 15.01 kg in the "warm water" zone (Table 7.1–10, Table 7.1–11 and Table 7.1–12) (*Research Study…, 2008*).

Table 7.1–10. Fish species composition, abundance (n), biomass (kg) and catches per unit effort (CPUE, 30 m long net) in the "cold water" zone of Lake Druksiai in 2007.

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Vendace	22	1.4	5.6	0.912	0.059	1.7
Pike	2	0.08	0.31	3.79	0.203	5.9
Roach	141	7.0	27.9	28.767	1.686	49.0
Bream	23	1.3	5.2	8.104	0.457	13.3
Silver bream	69	3.8	15.1	1.654	0.093	2.7
Bleak	3	0.16	0.64	0.008	0.0005	0.01
Tench	10	0.51	2.1	9.835	0.526	15.3
Rudd	2	0.08	0.31	0.345	0.018	0.5
Perch	159	9.4	37.4	6.29	0.382	11.1
Ruffe	23	1.4	5.6	0.258	0.015	0.4
Total:	327	25.13	100	59.963	3.439	100

Table 7.1–11. Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "cold water" zone of Lake Druksiai (profundal zone close to INPP intake) in 2007.

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Vendace	15	1.6	19.0	0.568	0.060	9.7
Pike	1	0.1	1.2	2.230	0.239	38.6
Silver bream	1	0.1	1.2	0.034	0.004	0.6
Perch	54	5.8	69.0	2.876	0.308	49.7
Ruffe	8	0.8	9.5	0.074	0.008	1.3
Total:	79	8.4	100	5.782	0.619	100

Table 7.1–12. Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "warm water" zone of Lake Druksiai in 2007.

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Roach	93	12.7	20.7	3.424	0.467	22.1
Bream	28	3.8	6.2	0.924	0.126	6.0
Silver bream	221	30.1	49.0	6.066	0.827	39.2
Rudd	1	0.1	0.2	0.054	0.07	3.3
Perch	89	12.1	19.7	4.349	0.593	28.1
Ruffe	19	2.6	4.2	0.194	0.026	1.2
Total:	451	61.4	100	15.011	2.109	100

Fish growth rates in Lake Druksiai changed after the operation of the INPP begun. During the first year of operation, growth rates of almost all fish species, increased, which was due to the rise in water temperature and widespread distribution of molluscs Dreissena (*Virbickas, 1988*).

The growth rates of many species in the "warm water" zone of the lake were faster than those in the "cold water" zone, which could be demonstrated by the comparison of roach and perch growth rates in two thermally different areas of the lake in 2005, i.e. "cold water" zone where the thermal contamination of the INPP was minimal, and the "warm water" zone where water temperature was 4–6°C above the norm. The growth rates of both roaches and perches were considerably faster in the "warm water" zone as regards all middle-age groups.

It can be concluded that the fish community of Lake Druksiai has changed along with the thermal and trophic trends. During a quite short period the fish community of the lake passed over several stages of succession, the rates of succession being tenths of times higher than those in the natural lakes. The species diversity decreased from 23-26 fish species (before launching the INPP) to the current list of 14 species. Abundance of previously dominant stenothermal coldwater fish decreased to the critical level: the lake smelt got extinct, while the vendace accounts for merely ca. 3 % of the total number of fish. Latterly, the fish community is composed basically of 3 eurythermal species: silver bream (32.9 % of the total fish abundance), perch (30.1 %) and roach (21.7 %).

Fishing in Lake Druksiai

Data on commercial fisheries in Lake Druksiai have been collected from 1950 (*Bružinskienė, Virbickas, 1988*). Commercial catches of fishermen were approximately 18.62 t of fish each year during the period 1950–1973, ranging from 6.23 to 36.4 t. The main catch was smelt (38.1 %). The share of bleak in the catches reached 6 t and sometimes more. Catches of vendace were relatively high in some years, e.g. 8 t in 1973. However, considering the large area of the lake, such catches were comparatively low and amounted to 4.4 kg/ha only.

Fishery was not intensive as indicated by age composition of the catches. Common bream were 6-22 years old (predominantly 8–17 years old), pike were represented by 2-14 (5-7), roach – 4-18 (12-15), perch – 4-14 (5-10), vendace – 2-6 (2-3) and smelt by 2-3 years old individuals.

Since the beginning of INPP operation, catches of roach, common bream and bleak increased. At the same time the share of smelt, vendace and pike decreased. During 1974–1983 the average catch per year was 23.43 t (5.5 kg/ha). Catches consisted predominantly of bleak (39.3 %), vendace (14.4 %), roach (13.9 %) and smelt (11.4 %).

Total commercial catches of fish, following the beginning of INPP operation, increased from 18.6 t (4.4 kg/ha) in 1950–1973 to 23.4 t (5.5 kg/ha) in 1974–1983 (Table 7.1–13) (*Research Study…, 2008*).

Table 7.1–13. Commercial catches (t/a) in Lake Druksiai in 1950–1973 and 1974–1983.

Species	1950–1973			1974–1983		
	min	max	mean	min	max	mean
Vendace	0.03	8	1.8	0.01	8.5	3.4
Smelt	0.08	13.1	7.5	0.1	12	2.7
Pike	0.4	2.1	2.3	0.5	4	1.4
Roach	0.4	2.4	0.7	0.2	12.7	3.3
Bleak	0.2	6.8	2.3	0.3	18.4	9.2
Bream	0.04	2.8	0.5	0.3	2.6	1.6

Species	1950–1973			1974–1983		
	min	max	mean	min	max	mean
Perch	0.6	6.6	1.7	0.2	1.6	0.7
Other species	0.06	6.2	1.8	0.01	11.6	1.2
Total	1.9	36.4	18.6	9.2	43.9	23.4
kg/ha	1.4	8.6	4.4	2.1	10.1	5.5

Concerning fishery, Lake Druksiai is a highly productive water body intensively used by anglers, but insufficiently exploited by commercial fishery. In 2007, fish stocks of the lake averaged ca. 671.78 t, and the commercial fish catch limit was ca. 67.180 t, or 18.5 kg/ha. Compared with fish stocks of 1994–1999 (ca. 737.59 t), the decrease was ca. 9 % (Table 7.1–14) (*Research Study…, 2008*).

Table 7.1–14. Fish stocks (kg) and commercial production (kg) per year in Lake Druksiai.

Species	Estimation of the size of the fish stocks (kg)	Total catch (kg)		
		Total	Maximum permissible catch of recreational fishery	Maximum permissible catch of commercial fishery
Perch	94860	9486	4743	4743
Roach	290860	29086	14543	14543
Pike	46800	4680	2340	2340
Bream	81740	8174	2452	5722
Tench	93850	9385	2815	6570
Vendace	11410	1141	0	1141
Other	52260	5226	2613	2613
Total	671780	67178	29506	37672

The stocks of some low-value and rarer species have been assessed based on the actual data of experimental fishing; therefore, precise calculations cannot be made. In fact, the general productivity of these species might be higher. This concerns productivity of populations of bleak, burbot, rudd and silver bream. The most remarkable decreases have been registered in the stocks of perch (from 180.5 t to 94.86 t) and vendace (from 30.56 t to 11.4 t). The biomass of other species decreased insignificantly. Tench stocks increased from 7.14 t to 93.85 t, and pike stocks increased from 7.81 t to 46.8 t.

Statistical data show that in 1950–1973 commercial catches used to be 18.6 t (4.4 kg/ha) on average, and in 1974–1983 they increased up to 23.4 t (5.5 kg/ha) (*Bruzinskienė, Virbickas, 1988*). Currently, commercial fishing is not actually pursued, e.g., the catches in 2005–2007 averaged merely 0.381 t (*Research Study…, 2008*).

7.1.1.6 Radionuclides in the water of Lake Druksiai and groundwater

Permission to release radionuclides from nuclear installations into environment is issued by the Ministry of Environment according to the requirements of the normative document LAND 42-2007 “On the Restrictions on the Release of Radionuclides from Nuclear Installations and Procedure for the Authorisation of Release of Radionuclides and Radiological Monitoring” (*State Journal, 2007, No. 138-5693*). According to the existing rules, the Ministry of Environment issues permissions for INPP for releases of radioactive substances into the environment.

Activity of radioactive materials discharged by INPP into Lake Druksiai is constantly observed by carrying out the monitoring. Information on radionuclides in effluents into the lake is presented in Table 7.1–15 (*INPP report ПТООт-0545-15, 2008*). It can be seen that activities of majority waterborne radionuclide releases is only 0.00–2.94 % of the limit values indicated in the permit of the Ministry of Environment of December 16, 2005 for activities of waterborne radionuclide releases. Activity of released Sc-90 constitutes 27 % from the activity limit, and activity of released tritium forms 11.9 % from the activity limit.

Lithuanian Hygiene Standard HN 87:2002 (*State Journal, 2003, No. 15-624*) requires that the annual effective dose to the critical group members due to operation and decommissioning of nuclear facility shall not exceed a dose constrain of 0.2 mSv/year.

Data on the annual effective doses to the critical group of the population due to radionuclides released into Lake Druksiai in 2000–2007 is presented in Table 7.1–16 (*INPP report PTOot-0545-15, 2008*). In the Annex 3 of LAND 42-2007 (*State Journal, 2007, No. 138-5693*) description of limitations on radionuclides releases from Ignalina NPP is provided. It is specified that in order not to exceed the dose constraint, the releases to atmosphere and water shall not exceed 0.1 mSv/year for each release pathway. Therefore, effective annual dose from each release pathway to members of the critical group of population is compared with 0.1 mSv/year. The actual annual effective dose due to radioactive waterborne releases from Ignalina NPP is about 1–2 % of the 0.1 mSv/year.

Table 7.1–15. Activity (MBq/year) of radionuclides released into Lake Druksiai during 2000–2007 and annual limit values set down in the permission No. 1 of the Ministry of Environment dated December 16, 2005.

Nuclide	Year								Annual limit value	Released % of annual limit value
	2000	2001	2002	2003	2004	2005	2006	2007		
Cs-137	45.5	512	1190	386	245	21.4	24.6	611	20800	1.82
Cs-134	0	1.2	0	0.2	0	0	0	58.7	255.7	2.94
Mn-54	0.3	67.6	0.4	2.4	0.6	0.09	0	0	4374	0.2
Co-58	0	15.4	0	0.4	0	0	0	0	634.8	0.31
Co-60	39.9	424	8.1	0.9	17.9	10.7	0	10.7	37040	0.17
Fe-59	0	92.1	0	1.9	0	0	0	0	872.9	1.35
Cr-51	0	79.9	0	0.9	0	0	0	0	1323	0.76
Zr-95	0	83.8	0	0.4	0.2	0	0	0	670	1.57
Nb-95	0	129	0	0.7	0.3	0	47.9	0	975.7	2.28
I-131	0	0	0	0	0	0	0	0	8641	0
Sr-90	350	91	496	0	365	411	0	0	793.5	27
H-3	8.7×10^5	5.7×10^5	9.7×10^5	6.8×10^5	7.5×10^5	3.24×10^6	5.76×10^5	6.48×10^5	8.73×10^6	11.9

Table 7.1–16. Annual dose (Sv) to critical group members of the population (during 2000–2007) due to radionuclides released to Lake Druksiai (*INPP report PTOot-0545-15, 2008*).

Nuclide	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
Cs-137	$1.09\cdot10^{-7}$	$1.23\cdot10^{-6}$	$2.85\cdot10^{-6}$	$9.26\cdot10^{-7}$	$5.88\cdot10^{-7}$	$5.1\cdot10^{-8}$	$5.98\cdot10^{-8}$	$1.47\cdot10^{-6}$
Cs-134	–	$9.09\cdot10^{-9}$	–	$1.71\cdot10^{-9}$	–	–	–	$4.34\cdot10^{-7}$
Mn-54	$3.0\cdot10^{-11}$	$5.54\cdot10^{-9}$	$3.0\cdot10^{-11}$	$1.9\cdot10^{-10}$	$4.8\cdot10^{-11}$	$7.4\cdot10^{-12}$	–	–
Co-58	–	$4.0\cdot10^{-10}$	–	$1.0\cdot10^{-11}$	–	–	–	–

Nuclide	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
Co-60	$4.79 \cdot 10^{-8}$	$5.09 \cdot 10^{-7}$	$9.72 \cdot 10^{-9}$	$1.13 \cdot 10^{-9}$	$2.14 \cdot 10^{-8}$	$1.28 \cdot 10^{-8}$	–	$1.28\ 10^{-8}$
Fe-59	–	$1.57 \cdot 10^{-9}$	–	$3.0 \cdot 10^{-11}$	–	–	–	–
Cr-51	–	$1.0 \cdot 10^{-10}$	–	–	–	–	–	–
Zr-95	–	$4.4 \cdot 10^{-10}$	–	–	$1.11 \cdot 10^{-12}$	–	–	–
Nb-95	–	$1.80 \cdot 10^{-7}$	–	–	$9.7 \cdot 10^{-10}$	$4.41 \cdot 10^{-10}$	$6.71 \cdot 10^{-8}$	
I-131	–	–	–	–	–	–	–	–
Sr-90	$6.57 \cdot 10^{-7}$	$1.73 \cdot 10^{-6}$	$9.42 \cdot 10^{-7}$	–	$6.93 \cdot 10^{-7}$	$7.81 \cdot 10^{-7}$	–	–
H-3	$7.46 \cdot 10^{-8}$	$1.76 \cdot 10^{-7}$	$2.33 \cdot 10^{-7}$	$1.07 \cdot 10^{-7}$	$1.20 \cdot 10^{-7}$	$1.13 \cdot 10^{-7}$	$2.02 \cdot 10^{-8}$	$2.27\ 10^{-8}$
Total	$8.93 \cdot 10^{-7}$	$3.79 \cdot 10^{-6}$	$4.08 \cdot 10^{-6}$	$1.04 \cdot 10^{-6}$	$1.42 \cdot 10^{-6}$	$9.59 \cdot 10^{-7}$	$1.47 \cdot 10^{-7}$	$1.94\ 10^{-6}$
Total (from γ nuclides)	$1.57 \cdot 10^{-7}$	$1.93 \cdot 10^{-6}$	$2.86 \cdot 10^{-6}$	$9.30 \cdot 10^{-7}$	$6.10 \cdot 10^{-7}$	$6.41 \cdot 10^{-8}$	$1.27 \cdot 10^{-7}$	$1.91\ 10^{-6}$

The total average annual dose of the total doses during 2000–2007 given in Table 7.1–16 is 1.78 10^{-3} mSv/year. As mentioned above, the dose limit for release route into the water from INPP is 0.1 mSv/year. Therefore, the annual total dose to critical group members of the population constitutes only 1.78 % of this dose limit.

Volumetric radionuclide activities in the water of the monitoring wells of Ignalina NPP industrial site and the existing spent nuclear fuel storage facility in 2007 are provided in Table 7.1–17. Location of groundwater monitoring wells and groundwater flow directions are shown in Figure 7.1-22.

Table 7.1–17. Volumetric radionuclide activities in the water of the monitoring wells of Ignalina NPP industrial site and the existing spent nuclear fuel storage facility in 2007 (*INPP report PTOot-0545-15, 2008*).

Well No.	Volumetric activity, Bq/l					
	Cs-137	Mn-54	Co-60	Nb-95	Sr-90	H-3
Industrial site						
29201	$1.09 \cdot 10^{-3}$	0	0	0	3.37·10-3	203
29202	$1.15 \cdot 10^{-3}$	0	0	0	$9.24 \cdot 10^{-4}$	1440
29205	$1.42 \cdot 10^{-3}$	0	$2.39 \cdot 10^{-2}$	0	$7.10 \cdot 10^{-4}$	743
29206	$8.35 \cdot 10^{-4}$	0	0	0	$1.24 \cdot 10^{-3}$	1.93
29208	0	0	0	0	$9.63 \cdot 10^{-4}$	13.2
29210	0	0	0	0	$1.42 \cdot 10^{-3}$	9.05
29214	0	0	$1.15 \cdot 10^{-2}$	0	$1.05 \cdot 10^{-3}$	0
29216	$1.15 \cdot 10^{-3}$	0	$9.60 \cdot 10^{-3}$	0	$6.05 \cdot 10^{-3}$	20.4
29217	0	0	0	0	$6.01 \cdot 10^{-3}$	106
29218	0	0	0	0	$4.53 \cdot 10^{-3}$	13.9
29219	0	0	0.40	0	$4.64 \cdot 10^{-4}$	1240
29222	$1.06 \cdot 10^{-3}$	0	0	0	$1.34 \cdot 10^{-3}$	5.35
29223	$1.20 \cdot 10^{-3}$	0	$3.15 \cdot 10^{-3}$	0	$3.23 \cdot 10^{-3}$	7.92
29522	0	0	0	0	$1.34 \cdot 10^{-3}$	2.00
29523	$1.39 \cdot 10^{-3}$	0	$3.77 \cdot 10^{-2}$	$5{,}60 \cdot 10^{-4}$	0	227
29524	0	0	0	0	0	61.7
29525	$2.80 \cdot 10^{-3}$	0	$7.43 \cdot 10^{-3}$	0	$2.52 \cdot 10^{-3}$	288

Well No.	Volumetric activity, Bq/l					
	Cs-137	Mn-54	Co-60	Nb-95	Sr-90	H-3
29526	0	0	0	0	$6.96{\cdot}10^{-4}$	4.48
29527	0	0	0	0	$3.13{\cdot}10^{-3}$	14.5
29528	$8.80{\cdot}10^{-4}$	0	$4.57{\cdot}10^{-3}$	0	$3.46{\cdot}10^{-3}$	13.5
29529	0	0	0	0	$6.30{\cdot}10^{-4}$	6.95
29530	0	0	0	0	$4.70{\cdot}10^{-4}$	4.05
29531	0	0	0	0	$6.35{\cdot}10^{-4}$	14.4
29532	0	0	0	0	$9.01{\cdot}10^{-4}$	8.15
29533	0	0	0	0	$1.72{\cdot}10^{-3}$	13.9
29534	$7.35{\cdot}10^{-4}$	0	0	0	0	5.44
29535	0	0	2.32	0	$8.35{\cdot}10^{-4}$	5920
29536	0	0	2.63	0	$1.71{\cdot}10^{-3}$	6450
29537	0	0	$1.00{\cdot}10^{-2}$	0	$4.11{\cdot}10^{-4}$	79.5
29538	$1.00{\cdot}10^{-3}$	0	0	0	$1.06{\cdot}10^{-3}$	20.1
29539	0	0	0	0	$1.04{\cdot}10^{-2}$	76.6
29540	0	0	0	0	$3.19{\cdot}10^{-3}$	368
29541	0	0	$1.75{\cdot}10^{-2}$	0	$6.90{\cdot}10^{-4}$	2500
29542	$2.82{\cdot}10^{-3}$	0	$1.22{\cdot}10^{-2}$	0	$1.23{\cdot}10^{-2}$	131
29543	0	0	0	0	$1.38{\cdot}10^{-3}$	6.15
29544	0	0	0	0	$1.25{\cdot}10^{-3}$	9.85
29545	0	0	0	0	$6.45{\cdot}10^{-4}$	2.85
29546	0	0	0	0	$6.15{\cdot}10^{-3}$	6.30
29547	0	0	0	0	$1.03{\cdot}10^{-2}$	6.95
29548	0	0	0	0	$2.32{\cdot}10^{-3}$	3.42
29549	0	0	$4.13{\cdot}10^{-3}$	0	$1.32{\cdot}10^{-2}$	2.54
29550	0	0	0	0	$7.70{\cdot}10^{-3}$	28.9
29551	0	0	0	0	0	5.05
29552	0	0	0	0	$2.53{\cdot}10^{-3}$	8.33
29553	0	0	0	0	0	18.2
29554	0	0	0	0	0	2.32
29555	0	0	0	0	$3.62{\cdot}10^{-4}$	3.53
29556	0	0	0	0	$9.35{\cdot}10^{-4}$	2.86
29557	0	0	$1.57{\cdot}10^{-2}$	0	$4.79{\cdot}10^{-3}$	3.50
29558	$1.33{\cdot}10^{-3}$	0	0	0	$3.52{\cdot}10^{-3}$	17.8
42564	0	0	0	0	$3.34{\cdot}10^{-2}$	97.8
42565	0	0	0	0	$4.40{\cdot}10^{-3}$	336
40281	0	0	0	0	0	3.33
40282	0	0	0	0	0	0
SFSF						
29559	0	0	0	0	0	4.68
29560	0	0	0	0	8.47·10-4	4.37
29561	0	0	0	0	$7.93{\cdot}10^{-4}$	4.87
29562	0	0	0	0	$1.19{\cdot}10^{-3}$	4.44
29563	0	0	0	0	$1.12{\cdot}10^{-3}$	5.20
29564	0	0	0	0	0	4.78
29565	0	0	$8.55{\cdot}10^{-3}$	0	0	5.25
29566	0	0	0	0	0	4.21

Well No.	Volumetric activity, Bq/l					
	Cs-137	Mn-54	Co-60	Nb-95	Sr-90	H-3
29567	0	0	0	0	0	4.65
29568	0	0	$1.07 \cdot 10^{-2}$	0	0	5.00
29569	$7.70 \cdot 10^{-4}$	0	0	0	$7.25 \cdot 10^{-4}$	4.79
29570	0	0	0	0	0	5.05
29571	0	0	0	0	$3.07 \cdot 10^{-3}$	4.98
29572	0	0	0	0	$<9.49 \cdot 10^{-4}$	3.90
29573	$2.71 \cdot 10^{-3}$	0	0	0	$1.25 \cdot 10^{-3}$	0
29574	0	1.93·10-3	0	0	$<1.06 \cdot 10^{-3}$	0
29575	$5.50 \cdot 10^{-4}$	0	$6.35 \cdot 10^{-3}$	0	$<9.26 \cdot 10^{-4}$	0
29576	$1.00 \cdot 10^{-3}$	0	$5.55 \cdot 10^{-3}$	0	$<1.22 \cdot 10^{-3}$	1.78
29577	0	0	0	0	$3.71 \cdot 10^{-3}$	1.74
Reworked quarry for storage of wastewater treatment sludge						
35219	0	0	0	0	$1.04 \cdot 10^{-2}$	4.34
35221	0	0	$1.65 \cdot 10^{-2}$	0	$1.90 \cdot 10^{-3}$	5.32
35222	0	0	0	0	$<1.13 \cdot 10^{-3}$	0

Radiochemical analysis of Sr-90 and gamma spectral measurements of radionuclides in the water of the monitoring wells, performed in 2007, show that the volumetric activities of radionuclides remained at the previous year level and they were comparable to the background activities (except wells No. 29535, 29536, 29219). Volumetric activities of radionuclides in wells No. 29535, 29536, 29219 are the highest (Co-60 from 0.4 to 2.6 Bq/kg, Table 7.1–17).

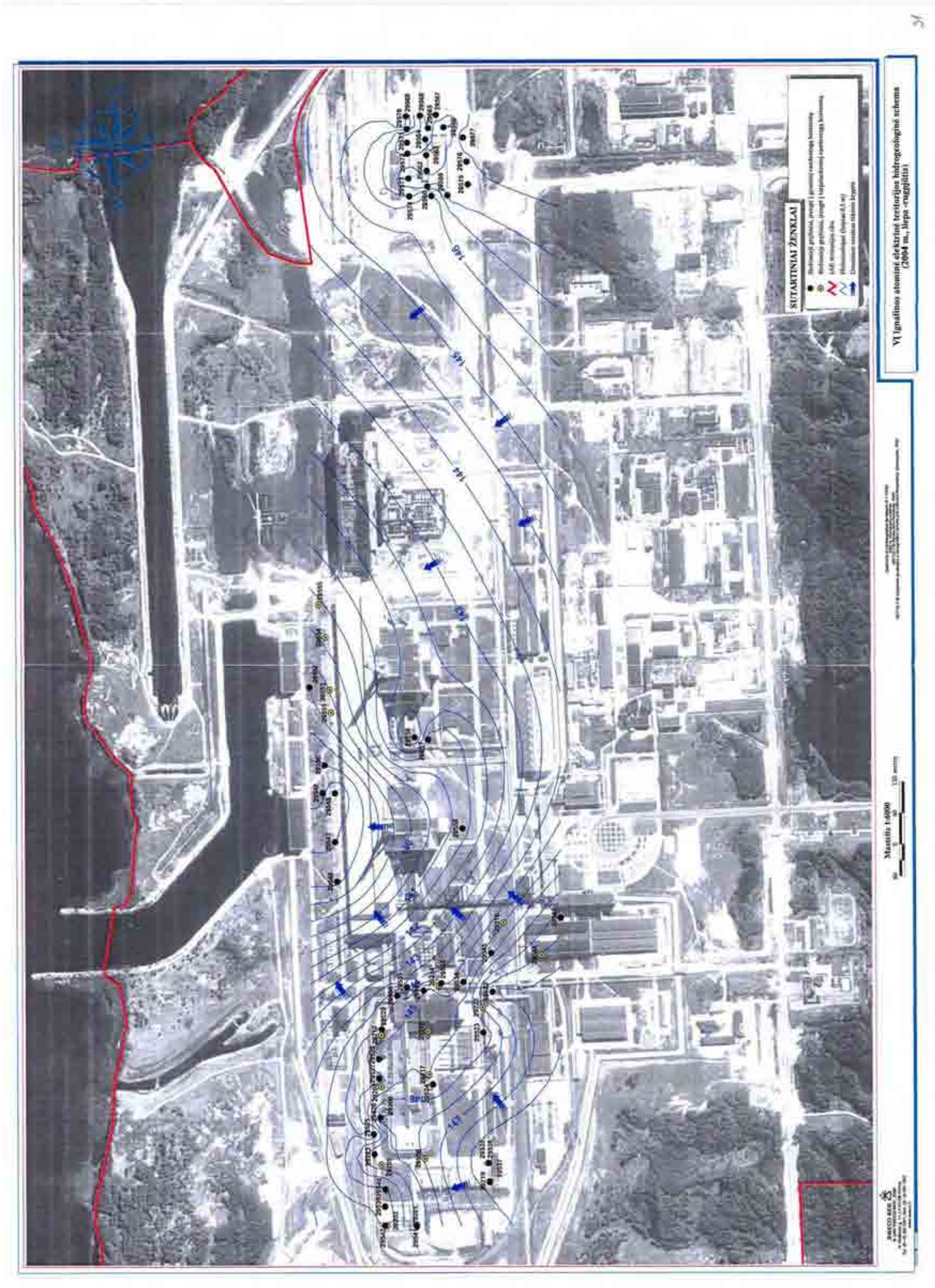


Figure 7.1-22. Hydrogeological system of the territory of Ignalina NPP (July – August, 2004), (*Report on the underwater monitoring of the main facility of State Enterprise "Ignalina nuclear power plant" of 2001-2005*).

In order to show the trends of alternation of the radionuclide activity concentrations within the territory of INPP it is expedient to provide perennial data rather than annual; this however would substantially increase the amount of data. Therefore, in order to optimize the amount of data presented, 5 observation wells with the highest radionuclide activity concentration (29202, 29219, 29535, 29541 and 2936) (Table 7.1–

18) and 5 observation wells closest to the site No. 1 of the new NPP, as well as surrounding it (29555, 29569, 29571, 29573 and 29574) (Table 7.1–19) have been selected.

Table 7.1–18. The perennial data of the 5 observation wells of the INPP industrial site with the highest radionuclide activity concentrations in the water. (*INPP Reports from ПТОот-0545-7 to ПТОот-0545-15*)

	Volumetric activity, Bq/l									
Well No.	**29202**		**29219**		**29535**		**29536**		**29541**	
Year	**Co-60**	**H-3**	**Co-60**	**H-3**	**Co-60**	**H-3**	**Co-60**	**H-3**	**Co-60**	**H-3**
1999	-	-	-	-	-	-	0	1.37 10^{1}	-	-
2000	0	0.99 10^{1}	-	-	-	-	0	1.22 10^{2}	-	-
2001	1.0 10^{-1}	0.31 10^{1}	-	-	-	-	3.0 10^{-3}	2.25 10^{2}	-	-
2002	0	4.27 10^{1}	0	9.46 10^{1}	3.1 10^{-1}	5.34 10^{2}	2.0 10^{-2}	2.34 10^{3}	3.0 10^{-2}	3.94 10^{3}
2003	5.0 10^{-2}	0.53 10^{1}	0	2.78 10^{1}	1.0 10^{-3}	1.67 10^{2}	1.7 10^{-2}	3.26 10^{3}	0	3.74 10^{3}
2004	1.0 10^{-2}	0.89 10^{1}	2.0 10^{-2}	4.6 10^{1}	3.2 10^{-1}	2.29 10^{3}	3.9 10^{-1}	1.04 10^{3}	5.0 10^{-2}	3.84 10^{3}
2005	1.5 10^{-3}	1.5 10^{1}	1.1 10^{-2}	4.7 10^{1}	9.2 10^{-1}	4.1 10^{3}	0.13 10^{1}	3.1 10^{3}	3.8 10^{-2}	2.4 10^{3}
2006	0	3.1 10^{2}	4.0 10^{-2}	1.6 10^{2}	0.16 10^{1}	4.1 10^{3}	0.24 10^{1}	3.9 10^{3}	3.6 10^{-2}	2.6 10^{3}
2007	0	1.44 10^{3}	4.0 10^{-1}	1.24 10^{3}	0.232 10^{1}	5.92 10^{3}	0.263 10^{1}	6.45 10^{3}	1.75 10^{-2}	2.5 10^{3}

Table 7.1–19. The radionuclide activity concentrations in the water of the 5 observation wells of the INPP industrial site and ISFSF closest the site No. 1 of the new NPP, as well as surrounding it. (*INPP Reports from ПТОот-0545-7 to ПТОот-0545-15*)

	Volumetric activity, Bq/l									
Well No.	**29555**		**29569**		**29571**		**29573**		**29574**	
Year	**Co-60**	**H-3**	**Co-60**	**H-3**	**Co-60**	**H-3**	**Co-60**	**H-3**	**Co-60**	**H-3**
1999	-	-	-	-	0	0.16 10^{1}	0	0.09 10^{1}	0	0.15 10^{1}
2000	-	-	-	-	0	0.055 10^{1}	0	0.034 10^{1}	0	0.076 10^{1}
2001	-	-	-	-	0	0.2 10^{1}	0	0.13 10^{1}	0	0.21 10^{1}
2002	0	0.13 10^{1}	0	0	0	0	0	0	0	0
2003	0	0.35 10^{1}	0	0	0	0.36 10^{1}	0	0	0	0.11 10^{1}
2004	0	0.15 10^{1}	0	0	0	0.18 10^{1}	0	0	0	0.055 10^{1}
2005	0	0.56 10^{1}	0	0.29 10^{1}	0	0.2 10^{1}	0	0.26 10^{1}	0	0.26 10^{1}
2006	0	0.62 10^{1}	0	0.32 10^{1}	0	0.4 10^{1}	0	0.29 10^{1}	0	0.27 10^{1}
2007	0	0.35 10^{1}	0	0.48 10^{1}	0	0.5 10^{1}	0	0	0	0

As it can be seen from the data submitted in Table 7.1–18, in recent years, the activity concentrations of both tritium and Co-60 in the water of the observation wells 29219, 29535 and 29536 have been quite significantly increasing, and the activity concentrations of Co-60 in the water of the observation wells 29202 and 29541 remain very low, although the activity concentrations of H-3 are relatively large. All of these wells are near to the existing solid radioactive waste storage facility: the well 29202 is adjacent to the west wall of Building 155/1 of the storage, 29541 - adjacent to the west wall of Building 155 of the storage, the wells 29219, 29535 and 29536 - adjacent to the south wall of Building 157/1 of the storage, therefore the reason of the groundwater radionuclide contamination does not raise any doubts. That reason is the leaks of the buildings of the existing solid radioactive waste storage. The safety analysis report of the existing solid radioactive waste storage facility performed by Swedish SKB ICAB (*Final safety analysis report of INPP solid radioactive waste storage facility, 2003*) concluded that Buildings 155, 155/1 157, 157/1 can be used as a storage facility not longer than until 2011. The solid radioactive waste at present stored within these buildings will be retrieved when the new INPP Solid Waste Management and Storage Facility will be commissioned. The solid waste retrieval facility (B2) in the framework of this project (B2/3/4) is foreseen to be commissioned at the beginning of 2011.

As it can be seen from the data submitted in Table 7.1–19, the situation is completely different in the other 5 wells that are closest to the site No. 1 of the new NPP and surround it. In the water of these observation wells, as in the majority of the other wells in the territory of INPP (Table 7.1–17), the radionuclide activity concentrations are close to zero or negligible. Therefore, it can be concluded that the reason of the increase in tritium concentration in some wells is not the operation of INPP major equipment, but the existing solid radioactive waste storage facility, which shall be emptied as soon as possible by retrieving and conditioning the solid waste stored there at present.

The measurements of ^{3}H and ^{14}C activity concentration in water from Lake Druksiai and other surface water bodies have been started already before INPP operation (*Jasiulionis et al., 1993; Mazeika et al., 1995; Mazeika et al., 1998*). After the start-up of INPP operation the new monitoring points on surface water bodies related to INPP industrial site were established: cooling water inlet channel (IC), heated water outlet channel (OC), industrial rain drainage (IRD) channels 1, 2, and 3 (Figure 7.1-23) (*Radiation Protection Centre Project Report, 2007*).

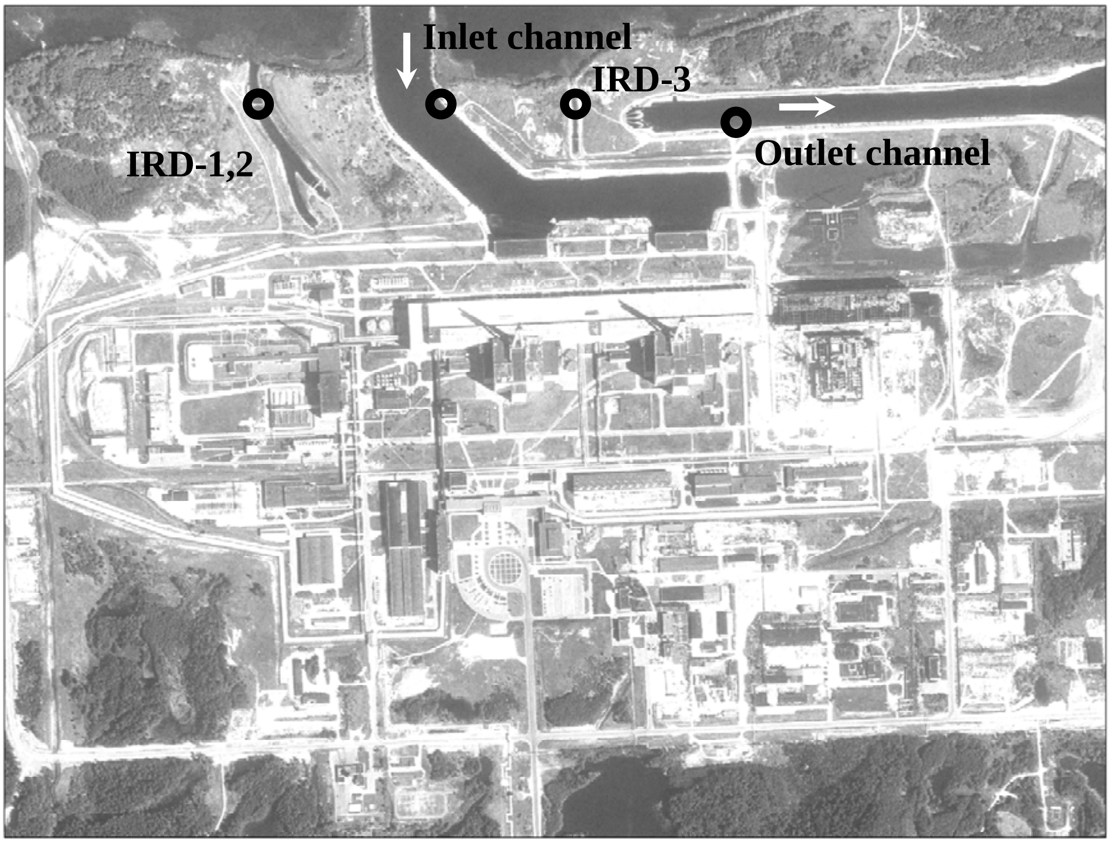


Figure 7.1-23. Observation points on main channels related to INPP industrial site.

The water samples for ^{3}H and ^{14}C measurements were usually taken 1–2 times a year. In the period of 2003–2004 ^{3}H activity in water was measured almost every month. Because of complicated methods for ^{14}C determination, the samples for the ^{14}C measurement in this period were taken only 1–2 times a year. Activity concentration of other radionuclides (^{90}Sr, ^{60}Co, ^{137}Cs) in surface water bodies were measured rarely (*Radiation Protection Centre Project Report, 2007*).

The measurements of ^{3}H and ^{14}C activity concentration in groundwater started in the period of INPP construction. In that time groundwater samples were taken from shallow dug wells in Kimbartiske, Antalge, Zibakiai rural localities. Systematic monitoring network for unconfined groundwater observation was established in 1987. There were about 30 observation wells with depth up to 10 m in the INPP region, including Lake Druksiai catchment territory in Belarus and Latvia. From that period about 15 observation wells remain in Lithuanian territory. The majority of observation wells are suitable for water sampling for ^{3}H measurements but none of them is suitable for ^{14}C activity measurement. The water inflow to the filters of observation wells is too low to collect necessary quantity of water for ^{14}C activity measurements (Radiation Protection Centre Project Report, 2007). The general view of groundwater monitoring network is shown in Figure 7.1-24.

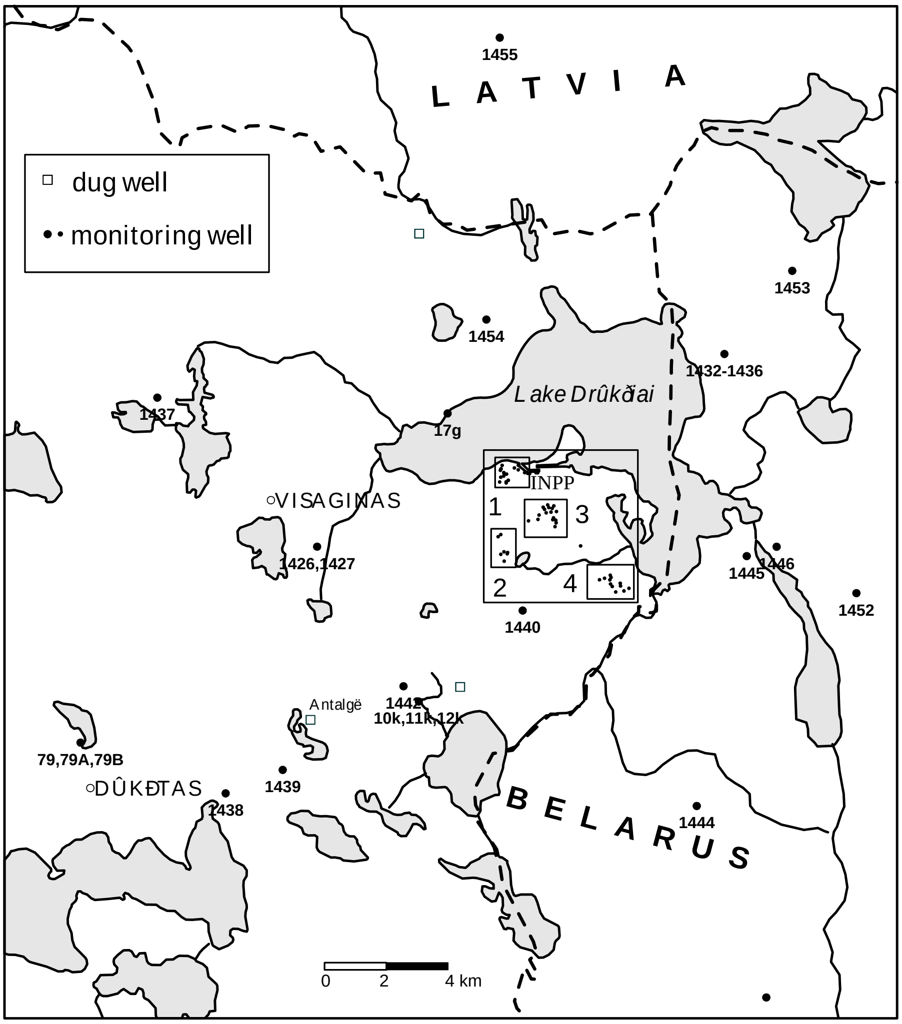


Figure 7.1-24. Groundwater monitoring network in the INPP region existed in different periods (*Radiation Protection Centre Project Report, 2007*).

On this scheme the first group of observation wells is located close to the radioactive waste storage area of the INPP in the western part of the INPP industrial site between NPP and the Lake Druksiai. The second group of observation wells is located in the surroundings of Visaginas wastewater treatment plant. The third group of observation wells is located in Stabatiske site and the fourth in Galilauke site (Radiation Protection Centre Project Report, 2007).

The activity concentration of ^{14}C in environmental samples was measured by liquid scintillation counting on benzene prepared from sample material as described in Gupta and Polach 1985. The ^{3}H activity concentration in surface water, groundwater and water extracted from biota was also measured by liquid scintillation counting of water sample mixed with scintillation cocktail (*LST ISO 9698:2006*).

An intensive monitoring study of radionuclides in the environment was carried out in 2007 (Radiation Protection Centre Project Report, 2007). ^{3}H activity concentration was measured from 6 surface water samples and ^{14}C activity concentration was measured from 3 surface water samples. From groundwater monitoring wells 17 water samples were taken for ^{3}H activity concentration analysis. ^{14}C activity concentration was measured from 4 groundwater samples. Gamma ray emitting radionuclides and ^{90}Sr were measured from 5 groundwater samples. ^{3}H and ^{14}C activity concentrations were also measured from other objects such as birch sap, aquatic and terrestrial plants and bottom sediments. The main results of the study are presented in Table 7.1–20, Table 7.1–21 and Table 7.1–22.

Table 7.1–20. ^{3}H and ^{14}C activity concentration in surface water in 2007 (*Radiation Protection Centre Project Report, 2007*).

No	Sampling point location	Sampling date	^{3}H, Bq/l ±1σ	^{14}C, Bq/m^{3} ±1σ
1	Zarasai district, Smalvele river	29-06-2007	1.3±0.4	6.8±0.3
2	INPP, inlet channel (IC)	28-06-2007	4.9±0.5	9.3±0.5
3	Lake Druksiai, 1 station, top water	27-06-2007	4.2±0.5	8.9±0.2
4	Lake Druksiai, 1 station, bottom water	2007-06-27	5.4±0.5	-
5	IRD-1,2	28-06-2007	36.9±2.0	-
6	IRD-3	28-06-2007	16.9±1.0	-

Table 7.1–21. ^{3}H and ^{14}C activity concentration in groundwater in 2007 (*Radiation Protection Centre Project Report, 2007*).

No	Sampling point location	Sampling date	^{3}H, Bq/l ±1σ	^{14}C, Bq/m^{3} ±1σ
1	Zarasai district., Budiniai, well 17g	02-04-2007	1.6±0.4	-
2	Zarasai district., Budiniai, well 17g	28-06-2007	1.2±0.4	-
3	INPP region, Stabatiske, well 6k	02-04-2007	1.3±0.4	-
4	INPP region, Stabatiske, well 6k	29-06-2007	0.5±0.4	11.0±0.1
5	INPP region, Grikiniske, piezometer	28-06-2007	1.1±0.4	-
6	INPP region, piezometer 40036p	28-06-2007	2.5±0.5	-
7	INPP region, well 40036	28-06-2007	2.5±0.5	20±0.2
8	INPP region, well 40035	28-06-2007	1.0±0.4	16.4±0.2
9	INPP region, Stabatiskes, well 4	28-06-2007	1.4±0.4	-
10	INPP region, well 71z	28-06-2007	4.6±0.5	-
11	INPP region, well 1431	29-06-2007	2.7±0.5	-
12	INPP region, well 35955	29-06-2007	0.3±0.4	-
13	INPP region, well 1430	28-06-2007	2.7±0.5	-
14	INPP region, well 1429	28-06-2007	3.7±0.5	-
15	INPP region, well 35221	29-06-2007	1.5±0.5	40.4±0.4
16	INPP region, well 35219	29-06-2007	1.1±0.5	-
17	INPP region, well 35220	29-06-2007	7.1±0.7	-

Table 7.1–22. ^{90}Sr, ^{137}Cs and ^{60}Co activity concentration in groundwater in 2007 (*Radiation Protection Centre Project Report, 2007*).

No	Sampling point location	Sampling date	Activity concentration, Bq/m^3 ±1σ		
			^{90}Sr	^{137}Cs	^{60}Co
1	INPP region, well 1429	28-06-2007	33±4	<1.5	<1.5
2	INPP region, Grikiniske	29-06-2007	1.0±0.3	<1.4	<1.5
3	INPP region, well. 35955	29-06-2007	30±4	<1.1	<1.1
4	INPP region, well 40035	28-06-2007	<1	<1.0	<1.0
5	INPP region, well 35221	29-06-2007	<1	<2.1	11.5±1.7

The measurements of ^{3}H activity concentration in water from Lake Druksiai occurred with different frequency. ^{3}H activity concentration trend line of the background water bodies (Lake Druksiai till 1984, Lake Dysnos and Smalvele River for later years) is decreasing. This is due to the decrease of ^{3}H, originating from the thermonuclear weapon tests, almost to the level of ^{3}H activity which corresponds to the cosmogenic production of ^{3}H. The difference between the background water bodies and Lake Druksiai display the increase of ^{3}H activity concentration originating from the radioactive effluents released by the INPP during normal operation. For the period of 1980–2007 the highest ^{3}H activity concentration in Lake Druksiai was observed in year 2003 and reached 24 Bq/l. ^{3}H activity concentration in Lake Skripkos located next to the Visaginas wastewater treatment plant was highest in 2000 and reached 30 Bq/l. During this period ^{3}H activity concentration in the background water bodies was 2–3 Bq/l, therefore approximately 20–25 Bq/l originated from INPP releases (Figure 7.1-25).

The ^{3}H concentration in the additional monitoring points on surface water bodies such as cooling water inlet channel (IC), heated water outlet channel (OC), industrial rain drainage (IRD) channels 1, 2 and 3 has been systematically measured since 1992. The same ^{3}H background line has been applied to this data. ^{3}H activity concentrations in the channels exceeded the background level during the whole period of observation.

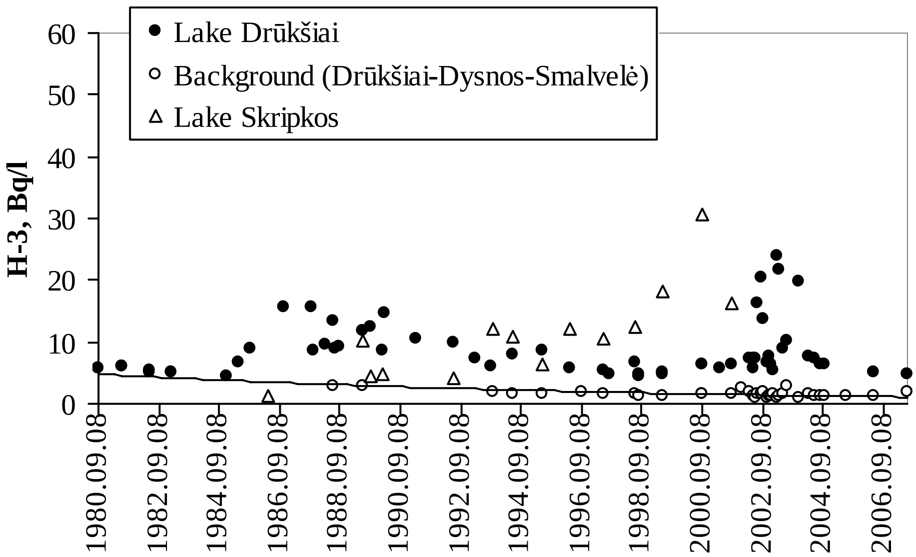


Figure 7.1-25. ^{3}H activity concentration in Lake Druksiai, Lake Skripkos and background water bodies in 1980–2007 (*Radiation Protection Centre Project Report, 2007*).

The flow rate of industrial rain drainage (IRD) channels 1 and 2, and especially that of channel 3 is low compared to the flow rate of the heated water outlet channel. Therefore radioactive effluents in IRD channels are less diluted and more variable in terms of ^{3}H activity concentration compared to the whole Lake Druksiai water body. The ^{3}H variations were investigated with higher temporal resolution in 2001–2004 when samples were taken more frequently – about once a month. At that time ^{3}H activity concentration in the water from channels 1 and 2 varied from 10 to 50 Bq/l (Figure 7.1-26).

Traces of ^{3}H originating from the INPP are found in the surface water. However, the impact on human and ecosystems is considered insignificant since the individual effective dose to critical group member is less than 0.02 μSv/year.

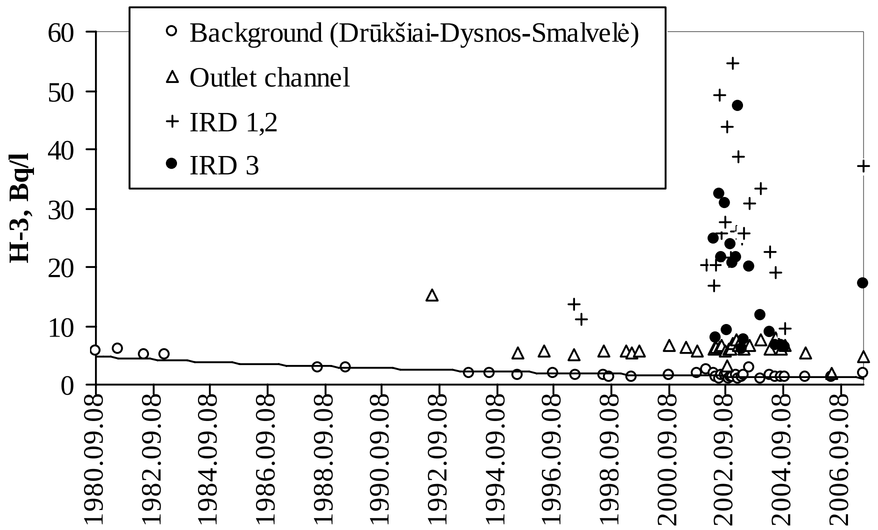


Figure 7.1-26. ^{3}H activity concentration in channels related to industrial site of INPP in 1980–2007 (*Radiation Protection Centre Project Report, 2007*).

^{14}C activity measurements in DIC of surface water bodies started in 1975. Water samples were taken with varying frequencies (Figure 7.1-27).

^{14}C activity concentration in background water bodies is parallel to the international data for Northern Hemisphere. The excess of ^{14}C originated from thermonuclear weapon tests declined almost to the ^{14}C level of cosmogenic origin for all studied surface water bodies. From period of 1992–1993 in the atmosphere and in the surface water all over the world predominates ^{14}C of cosmogenic origin. Almost for the whole period of the ^{14}C monitoring in surface water the influence of INPP has been hardly detected. ^{14}C activity concentration in water from Lake Druksiai and from the cooling water inlet channel has increased in 2001–2006, while it decreased again in 2007. The highest activity of ^{14}C, 13.6±0.2 Bq/m^{3}, was observed in 2005, while the background level was about 10.0±0.2 Bq/m^{3}. The increase of ^{14}C activity was about 3.6 Bq/m^{3}. The ^{14}C activity reduced in 2007 to 8.9 Bq/m^{3}.

Traces of ^{14}C originating from the INPP are found in the surface water. However, the impact on human and ecosystems is considered insignificant since the individual effective dose to critical group member is less than 0.5 μSv/year.

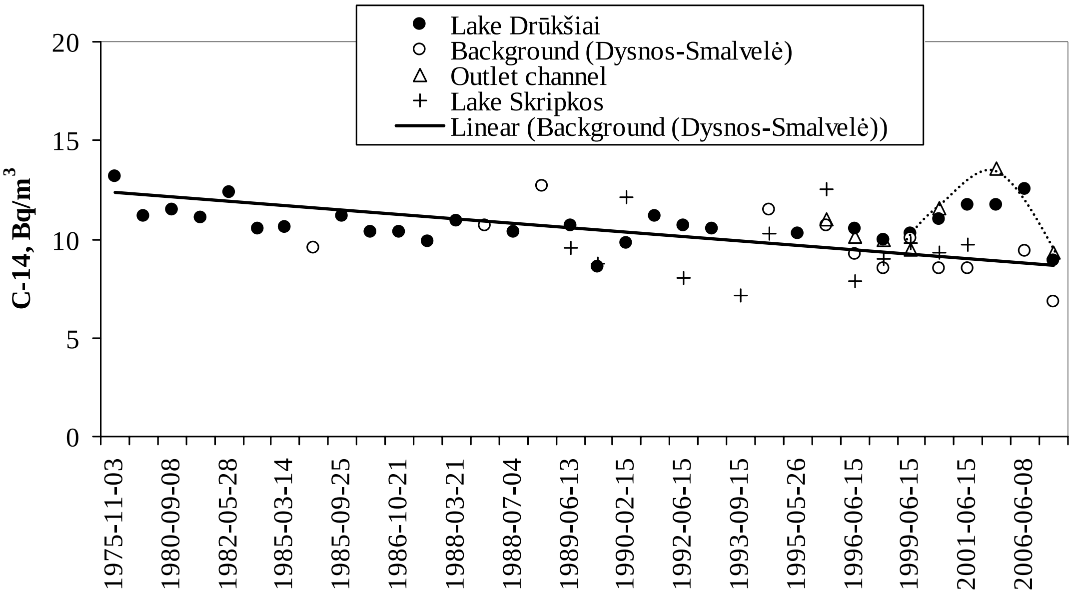


Figure 7.1-27. ^{14}C activity concentration in Lake Druksiai, Lake Skripkos, heated water outlet channel and background water bodies in 1975–2007 (*Radiation Protection Centre Project Report, 2007*).

^{3}H activity concentrations were measured systematically in the groundwater from monitoring wells 71z, 1429, 1430, 1431, which are located close to the INPP. These monitoring wells are located in line downflow from the INPP to Lake Druksiai. The ^{3}H concentrations in groundwater were monitored between 1987 and 2007 (Figure 7.1-28).

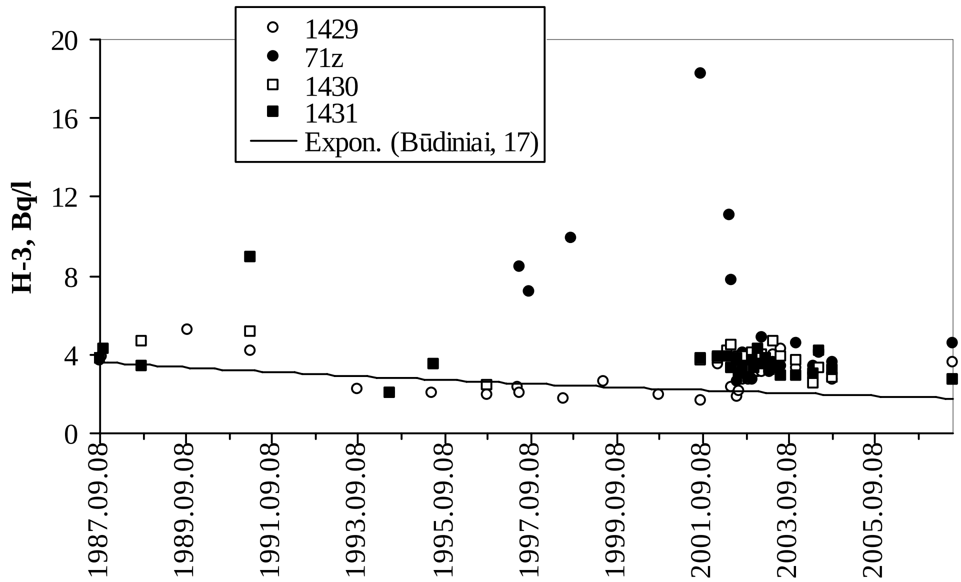


Figure 7.1-28. ^{3}H activity concentration in groundwater in 1987–2007 (*Radiation Protection Centre Project Report, 2007*).

Background samples were taken from the observation well Budiniai, 17. This well is located on the northern shore of Lake Druksiai and is not related to the INPP industrial site. ^{3}H activity concentration was higher than the background level only in observation piezometer 71z, which is closest to the INPP. The highest ^{3}H activity (18.3 Bq/l) was measured in 2001. ^{3}H background level at that time was about 2 Bq/l. In down-flow direction from INPP the level of ^{3}H activity in groundwater is decreasing and for the most part remains very close to the background level. The ^{3}H concentration in observation well 1431 installed very close to the lake was somewhat higher than the background level when there was inflow to the well from Lake Druksiai.

There are more ^{3}H data available than ^{14}C data of groundwater. The ^{14}C activity concentrations in groundwater from the years 1987–2007 are presented in Figure 7.1-29.

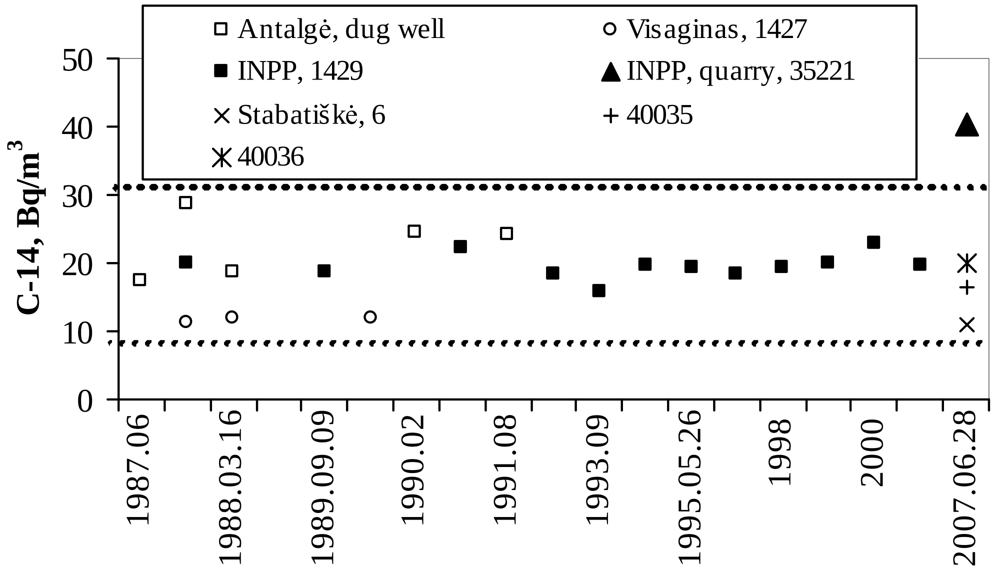


Figure 7.1-29. ^{14}C activity concentration in groundwater in 1987–2007 (dashed lines show ^{14}C background level range) (*Radiation Protection Centre Project Report, 2007*).

The ^{14}C activity in groundwater has never exceeded the global level. The influence of INPP has not been observed.

Large water volume (150–300 l) for ^{14}C activity measurements is required. Therefore it is possible to take samples only from a few observation wells located in the area of INPP. In 2007 it was observed that the ^{14}C activity level in the quarry observation well 355221 was somewhat higher than the activity caused by global sources. ^{14}C activity was 40.4±0.4 Bq/m^{3}. In the previous period the sludge from the Visaginas wastewater treatment plant was disposed of to the same quarry.

The activity of ^{90}Sr and gamma ray emitting radionuclides in groundwater was also measured together with ^{3}H and ^{14}C. Their activities were often very low and mostly less than minimal detectable activity (<MDA). Very insignificant activity concentration of ^{60}Co was determined in the water from quarry observation well.

7.1.1.7 Radioecological state of flora, fauna and bottom sediments of Lake Druksiai

Data on radionuclide concentrations in the algae samples, taken from the INPP region aqueous media in 2007, is presented in Table 7.1–23. Radionuclide specific activities of fish, caught in Lake Druksiai in 2007, are given in Table 7.1–24, and the average annual radionuclide specific activity of Lake Druksiai fish in 2000–2007, as well as ionizing radiation dose due to the consumption of fish are provided in Table 7.1–25 (*INPP report PTOot-0545-15, 2008*).

Table 7.1–23. Radionuclide specific activities in the algae samples, taken from the INPP region aqueous media in 2007 (*INPP Report ПТОот-0545-15, 2008*).

Sampling point		Specific activity, Bq/kg													
		Cs-137	Cs-134	Mn-54	Co-58	Co-60	Cr-51	Fe-59	Sr-90	K-40	Be-7	Th-232	Ra-226	Total	Total except for K, Be, Th, Ra
Lake Druksiai	Point 1	1.74	<AR	<AR	<AR	<AR	<AR	<AR	5.44	815	112	<AR	6.23	935	7.18
	Point 2	2.50	<AR	<AR	<AR	0.98	<AR	<AR	6.72	417	166	3.40	5.76	596	10.2
	Point 3	24.4	<AR	<AR	<AR	2.31	<AR	<AR	3.98	639	656	20.9	18.8	1360	30.7
	Point 4	9.93	<AR	0.79	<AR	1.01	<AR	<AR	3.73	705	329	18.1	53.8	1120	15.4
	Point 6	5.09	<AR	<AR	<AR	<AR	<AR	<AR	7.80	571	149	3.93	6.14	735	12.9
Discharge channel		15.1	0.84	11.7	2.45	10.7	10.6	10.7	7.02	874	417	8.98	11.5	1370	69.1
PLK-1		22.1	0.67	10.0	0	71.0	0	0	-	104	370	10.5	15.4	604	104
PLK-3		5.08	0.32	13.1	<AR	46.2	<AR	0.96	-	82.8	97.6	2.51	3.79	252	65.7
PLK of SFSF		5.44	0	0	0	0	0	0	-	886	143	24.4	18.3	1080	5.44
Discharge channel (microalgae)		45.8	9.83	95.3	18.5	78.7	97.4	94.8	-	725	725	27.7	30.4	1950	440
Intake channel (microalgae)		18.8	<AR	<AR	<AR	1.89	<AR	<AR	-	280	230	15.3	11.8	558	20.7

Cs-137 limit of detection (LOD) does not exceed 4.2 Bq/kg.

All the specific activities of radionuclides have been calculated for the dry mass. The algae were taken according to the monitoring program, if they were present in the channels. The main contribution to the total algae specific activity was made by the natural radionuclides K-40 and Be-7.

Table 7.1–24. Specific activities of radionuclides in the fish, caught in Lake Druksiai in 2007 (*INPP Report PTOot-0545-15, 2008*).

Fish species	Specific activity, Bq/kg			
	Cs-137	**Sr-90**	**K-40**	**Total, except for K-40**
Pike	1.22	0.21	109	1.43
Perch	2.45	0.41	91.4	2.86
Roach	0.55	1.05	65.1	1.60
Tench	0.61	0.18	85.0	0.79
Crucian	0.52	0.87	77.7	1.39
Bream	0.66	0.52	94.4	1.18
Average:	1.09	0.54	88.2	1.63

Table 7.1–25. Average annual specific activity of radionuclides in Lake Druksiai fish in 2000-2007 (*INPP Report ПТОот-0545-15, 2008*).

Year of sampling	Specific activity, Bq/kg						Dose due to fish consumption (except for K-40), µSv/m
	Cs-137	Cs-134	Co-60	Sr-90	K-40	Total, except for K-40	
2000	1.60	0	0	<20	63.5	1.60	0.21
2001	1.78	0	0	<20	93.5	1.78	0.23
2002	1.82	0	0	<38	127	1.82	0.23
2003	1.69	0	0	1.11	108	2.80	1.67
2004	1.10	0	0	1.52	101	2.60	1.70
2005	1.15	0	0	0.84	115	1.99	1.16
2006	0.99	0	0	0.56	109	1.55	0.86
2007	1.09	0	0	0.54	88.2	1.63	0.88

Research scope and methods

Samples of plants and bottom sediments were collected at the monitoring stations of Lake Druksiai and in the INPP industrial storm water discharge and cooling water channels in 1988–2004 and 2007, Figure 7.1-30 (Radiation Protection Centre Project Report, 2007). In addition samples of fish and mollusc were collected. Indicator organisms of flora in Lake Druksiai are presented in Table 7.1–26. Activity of ^{137}Cs, ^{90}Sr, ^{60}Co, ^{54}Mn and ^{90}Sr was measured according to the methods described by Gudelis et al,(*2000*), Luksiene et al (*2006*), Sokolova (*1971*), Pimpl (*1996*) and Suomela (*1993*) (Radiation Protection Centre Project Report, 2007).

Terrestrial plants for determination of the radioecological state of the Ignalina NPP region were collected in the reference sites of the region and in background monitoring stations of the regions of Lithuania (Figure 7.1-30). The indicator organisms of terrestrial flora and research results are presented in section 7.6.1.1.2.

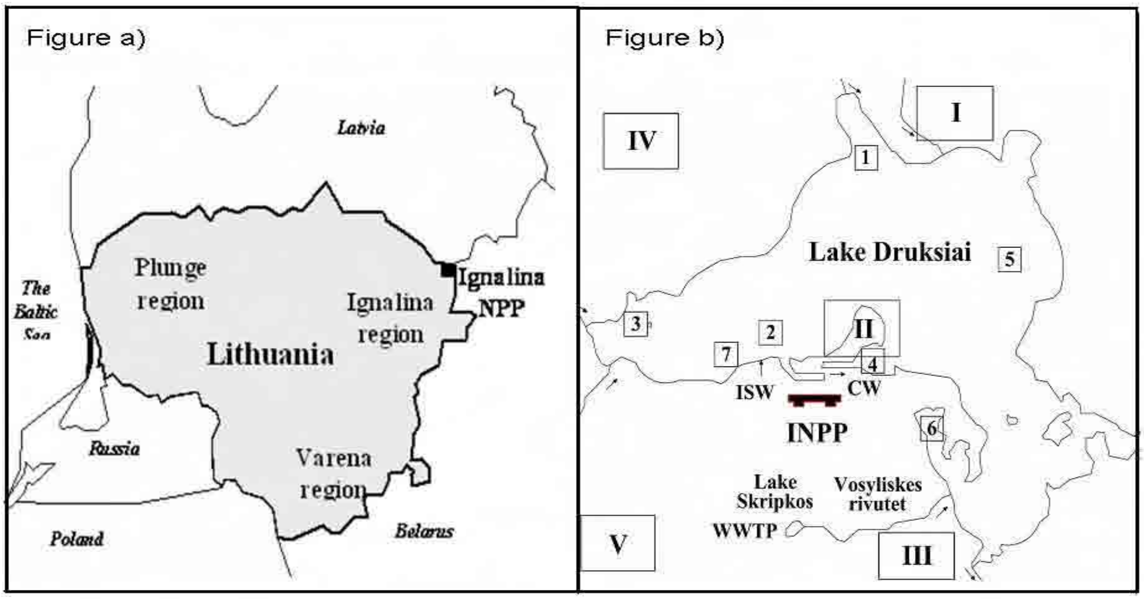


Figure 7.1-30. Regions of sample collection of water plants, bottom sediments and terrestrial plants: Figure a) Stations of background monitoring of the regions of Lithuania (Plunge, Varena, Ignalina); Figure b) Reference sites of the Ignalina NPP region (I – Tilze, II – Grikiniskiai, III – Vosyliskes, IV – Sakiai – Zavisiskes, V – Visaginas). Monitoring stations of the Lake Druksiai.[2]

Research results

The radioecological state of plants, bottom sediments, mollusc and fish of Lake Druksiai (1988–2007) is presented in this section.

The values of ^{137}Cs, ^{90}Sr, ^{60}Co and ^{54}Mn activities detected in plants and bottom sediments of Lake Druksiai in 1988–1999 were high depending on year and monitoring station. Highest values of ^{60}Co and ^{54}Mn activity in lake plants (respectively 200 and 90 Bq/kg) and bottom sediments (respectively 180 and 204 Bq/kg) were detected in the impact areas of the waste water of ISW and CW channels (7-th and 4-th monitoring station). In most cases highest values of activities of all analyzed radionuclides in bottom sediments and plants of Lake Druksiai were detected in the period 1988–1990. However, from 1994–1996 a tendency of reduction of radionuclides activity, especially ^{60}Co and ^{54}Mn, in plants and bottom sediments has been observed.

In 1996 ^{134}Cs activity varied between 2–52 and 2–20 Bq/kg in bottom sediments and plants in Lake Druksiai. In the period 1991–1997, values of ^{137}Cs activity levels of molluscs *Dreissena polymorpha* in Lake Druksiai, depending on the year of analysis and place of collection (monitoring station), ranged between 4–50 Bq/kg, ^{60}Co – 3–129 Bq/kg, ^{54}Mn – 1–56 Bq/kg, and ^{90}Sr – 24–94 Bq/kg dry weight (d.w.).

Highest values of activity of radionuclides in fish in Lake Druksiai were detected in 1988. Activity of ^{137}Cs in predatory fish (perch and Northern pike) was significantly higher than in cyprinid fish (roach and carp bream). However, activity of ^{137}Cs in both

[2] St. 1 – the furthest from the INPP; St. 2 – at the zone of the power plant water collection; St. 3 – to the west from the power plant by the Visaginas city (at the zone of industrial-storm water sewage discharge of the city); St. 4 – about 200 m from the cooling water discharge channel; St. 5 – at the end of the cooling water zone; St. 6 – to the east from the power plant, in the impact zone of waste water of the Visaginas municipal WWTP; St. 7 – close to the INPP, in waste water zone of industrial-storm water sewage discharge; CW – cooling water channel; ISW – channel of industrial-storm water and process water discharge; WWTP –Visaginas municipal waste water treatment plant.

predatory fish and cyprinid fish has dropped in 1994. Activities of ^{137}Cs in muscles of fish have been higher than in whole fish (Figure 7.1-31). Values of ^{90}Sr activity in fish did not depend on the nutrition. Values of ^{60}Co and ^{54}Mn activities in fish of Lake Druksiai have been low. (*Luksiene, 1995; Marciulioniene, Petkeviciute, 1997*).

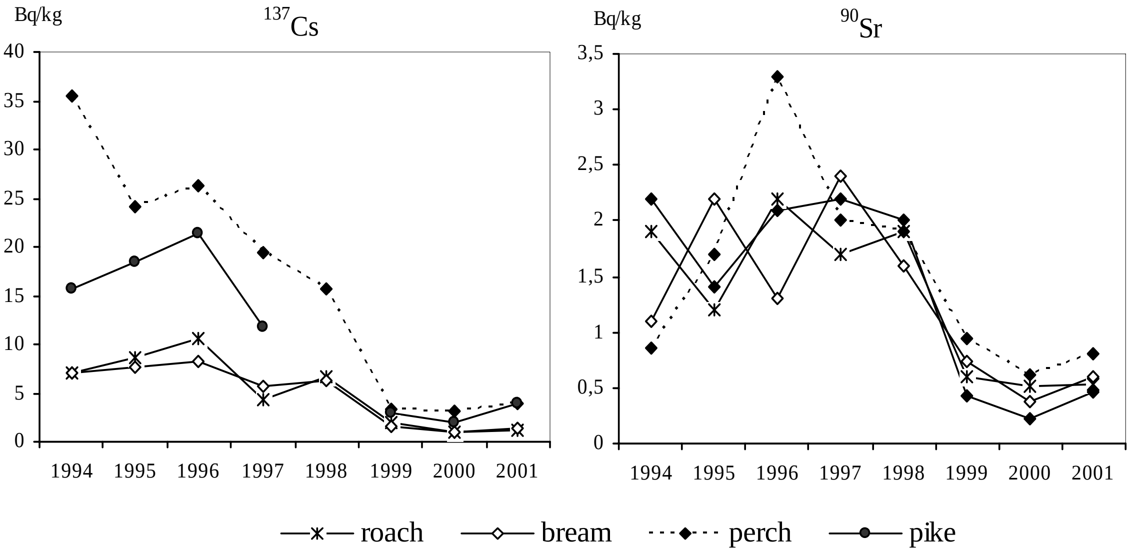


Figure 7.1-31. Annual changes of values of ^{137}Cs and ^{90}Sr activities (Bq/kg w. w.) in muscles of fish in Lake Druksiai.

According to the data of long-term analyses of radionuclide activity in bottom sediments, flora and fauna of Lake Druksiai, the radioecological state of the lake has constantly improved due to reduced penetration of radionuclides to the lake from Ignalina NPP. However, decreasing of the activity of ^{137}Cs has been rather low and in some areas of the bottom sediment values of ^{137}Cs activities have increased (Figure 7.1-32). In 2007, in bottom sediments of the Lake Druksiai values of ^{134}Cs activity were lower than minimum detectable level, and values of ^{60}Co and ^{54}Mn activity reached respectively 7.4 and 0.9 Bq/kg and were significantly lower than in period 1989–1996 (Figure 7.1-32).

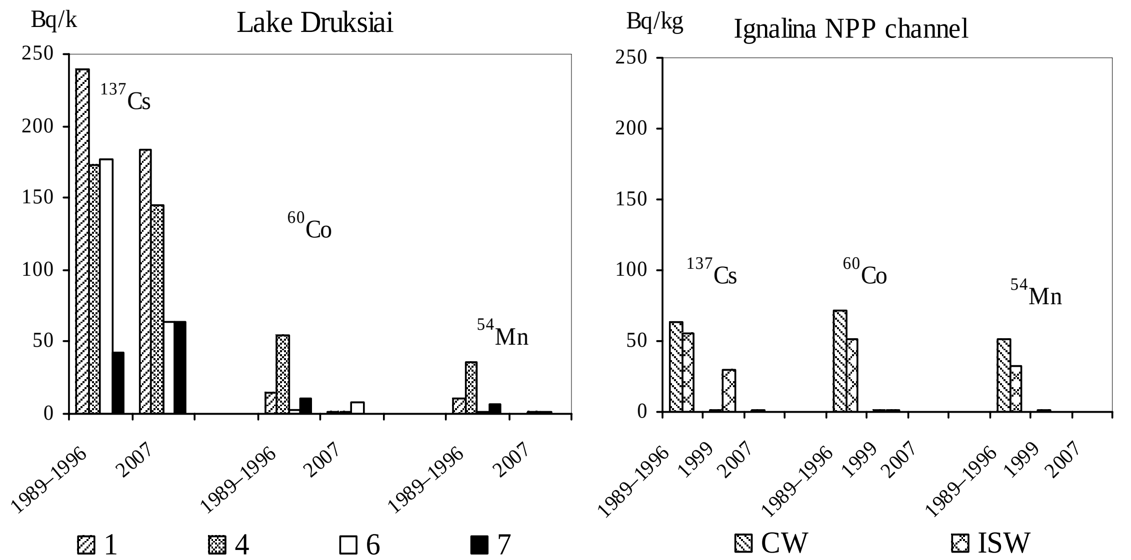


Figure 7.1-32. ^{137}Cs, ^{60}Co and ^{54}Mn activity (Bq/kg, d.w.) in bottom sediments of monitoring stations of Lake Druksiai (1-st, 4-th, 6-th, 7-th) and in ISW and CW channels of INPP in 1989–1996, 1999 and 2007.

In 2007, values of activity ^{90}Sr in bottom sediments of Lake Druksiai were very low (ranged between 0.5–2.5 Bq/kg). Slightly higher values of ^{90}Sr activity are provided in the INPP Report on the Results of Radiation Monitoring of the INPP region in 2007: ^{90}Sr concentration in the bottom sediments of Lake Druksiai at the points of zero background ranged from 1.85 to 5.87 Bq/kg (*INPP Report PTOot-0545-15, 2008*).

According to the data of D. Adliene and R. Adlyte (*2005*) the measured activity values in aquatic plants of Lake Druksiai during the period of 2001–2004 varied from 2.5 to 14 Bq/kg d.w. for ^{137}Cs, from 0.5 to 7.5 Bq/kg d.w. for ^{60}Co, and from 0.9 to 3.7 Bq/kg d.w. for ^{54}Mn.

In 2007, only two species of plants (macrophytes) were found in Lake Druksiai (Table 7.1–26). Values of ^{137}Cs activity in these plant species, depending on the place they were collected, ranged between 3–22 Bq/kg. ^{60}Co activity was detected only in plants at the 7-th and 4-th monitoring stations (respectively 42 and 1.3 Bq/kg) (Table 7.1–26). ^{54}Mn activity in the analyzed plants of Lake Druksiai was lower than minimum detectable level, except at the 7-th monitoring station, at which activity of radionuclide to plants was 2 Bq/kg (Table 7.1–26). Values of ^{90}Sr activity in the analyzed plants were very low and depending on place of their collection (monitoring station), ranged between 1.2–6.2 Bq/kg (Table 7.1–26).

Table 7.1–26. Activity of radionuclides (Bq/kg d. w.) in water plants of Ignalina NPP waste water channels and in Lake Druksiai in 2007.

Monitoring stations	Species	^{137}Cs	^{60}Co	^{54}Mn	^{90}Sr
Lake					
1-st station	*Ceratophyllum demersum*	22 ± 2	< mdl	< mdl	1.2 ± 0.3
	Myriophyllum spicatum	3 ± 0.4	< mdl	< mdl	2.5 ± 0.5
4-th station	*Ceratophyllum demersum*	7 ± 0.7	1.3 ± 0.2	< mdl	21.9 ± 0.4
6-th station	*Ceratophyllum demersum*	7 ± 0.7	< mdl	< mdl	6.2 ± 0.8
	Myriophyllum spicatum	4 ± 0.4	< mdl	< mdl	3.3 ± 0.6
7-th station	*Ceratophyllum demersum*	17 ± 2	42 ± 2	2 ± 1	2.9 ± 0.5
	Myriophyllum spicatum	4 ± 0.8	< mdl	< mdl	5.2 ± 1.0
Waste water channels					
CW channel	*Myriophyllum spicatum*	4 ± 0.8	< mdl	< mdl	6.6 ± 0.9
ISW channel	*Ceratophyllum demersum*	20 ± 2	34 ± 2	2 ± 0.6	2.3 ± 0.5

< mdl – under minimum detectable level

Values of ^{137}Cs and ^{60}Co activity in the plants from ISW channel were respectively 20 and 34 Bq/kg, and in plants from CW channel ^{137}Cs activity was 4 Bq/kg, ^{60}Co and ^{54}Mn activity was lower that minimum detectable level (Table 7.1–26). ^{90}Sr activity in plants in INPP channels reached 6.6 Bq/kg (Table 7.1–26).

Long-term research data show that from 1988 to 2007 in plants of Lake Druksiai a strong tendency of diminishing of ^{137}Cs activity has been observed (Figure 7.1-33). A similar tendency of diminishing of ^{60}Co and ^{54}Mn activities has been observed in plants of Lake Druksiai.

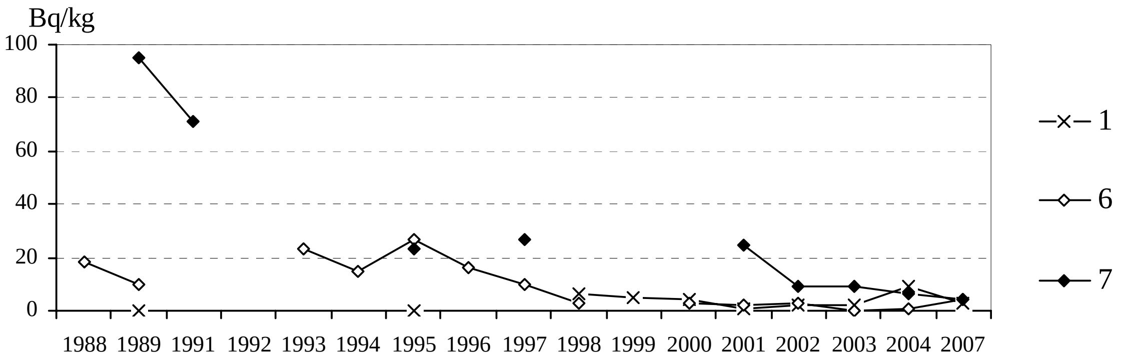


Figure 7.1-33. Annual changes of values of 137Cs activity (Bq/kg d. w.) in water plant *Myriophyllum spicatum* in 1-st, 6-th and 7-th monitoring stations of the Lake Druksiai.

In 2007 in molluscs of Lake Druksiai 1-st, 6-th and 7-th monitoring stations ^{137}Cs activity was respectively 5, 7 and 4 Bq/kg, and ^{60}Co and ^{54}Mn activities were lower than the minimum detectable level.

Long-term radioecological investigations of Lake Druksiai show that in 1988–2004, during operation of both units of INPP, the greatest values of activities of radionuclides (^{137}Cs, ^{134}Cs, ^{90}Sr, ^{60}Co ir ^{54}Mn) in the bottom sediments, flora and fauna of this lake were detected in the period 1988–1993. Since 1994, and in some cases since 1996, tendency of activity decrease (particularly of ^{137}Cs, ^{60}Co and ^{54}Mn) in the bottom sediments, flora and fauna of Lake Druksiai has been observed. Values of activities of ^{137}Cs and ^{90}Sr in plants, and especially in bottom sediments of Lake Druksiai were higher than at INPP channel of industrial-storm water and process water discharge (ISW) and cooling water channel (CW). Values of activities of ^{60}Co and ^{54}Mn, on the contrary, were lower in Lake Druksiai than in these INPP channels.

Summarizing data of long-term investigations, it may be stated that the radioecological state of Lake Druksiai has constantly improved during the operation of both units as well as after closure of the first unit of INPP.

7.1.1.8 Ecotoxicological state of Lake Druksiai

Research scope and methods

Samples of water and bottom sediments were collected at the monitoring stations of Lake Druksiai and in INPP industrial storm water discharge and cooling water channels and Visaginas municipal WWTP channel and route of the waste water of the WWTP into Lake Druksiai in 1988–2004 and 2007 (Figure 7.1-30). According to the bioassays applied in the ecotoxicological investigations distillate or artesian water was used as background water.

Toxicity and genotoxicity tests of INPP discharge channels and bottom sediments were carried out based on the biological tests widely used in the world (*EPA, 1996a, b; OECD, 2003; Minouflet et al., 2005*): common duckmeat (*Spirodela polyrrhiza* (L) Schleid.), garden-cress (*Lepidium sativum* L.) (*Magone, 1989; Montvydiene, Marciulioniene, 2004*); piderwort (*Tradescantia*) (*Marciulioniene et al., 2004*) and rainbow trout (*Oncorhynchus mykiss* Walbaum.) (*ISO, 1994; ISO, 1999; Vosyliene et al., 2005*). The level of toxic impact of water and bottom sediments on common duckmeat and garden-cress was assessed following methods suggested by Wang (*1992*), and genotoxic level to spiderwort, following methods suggested by Marciulioniene et al. (*1996*).

Research results

The impact of waste water of INPP on plant test-organisms in 1988–2000 and 2007 according to toxicity and genotoxicity scale differed slightly. In most cases, these waste waters caused a weak toxic impact or were non-toxic for common duckmeat and garden-cress, for spiderwort they were medium or strongly genotoxic. In 1988–2000 and 2007 from the INPP waste water flowing directly into Lake Druksiai the most toxic waste water for the tested plants was waste water from ISW channel. Waste water (after treatment) of Visaginas municipal WWTP and water of Lake Skripkos and Vosyliskes rivulet were more toxic to the tested plants than waste water of ISW and CW channels. Water of Lake Druksiai was mostly non-toxic for common duckmeat, slightly toxic or non-toxic for garden-cress, and for spiderwort water of the 6-th and the 7-th monitoring stations was medium, and for the 1-st station slightly or medium genotoxic. All tested waste water caused various (non-specific) morphological changes of common duckmeat.

In 1989–1996, the research performed by Dr. N. Kazlauskiene shows that waste water most toxic to embryos and larvae of rainbow trout within the waste water of INPP was waste water from the ISW channel. The water in the outlet areas of ISW and WWTP in Lake Druksiai has been marked by low toxicity, and water of the 1-st station was non-toxic. Comparison of the results of the toxicity of waste waters of INPP and water of Lake Druksiai obtained in 2007 with earlier investigations showed, that mortality of juveniles of rainbow trout in water of the 6-th and 7-th monitoring stations of Lake Druksiai has increased. However, impact of the waste water of INPP and water from the 1-st monitoring station of Lake Druksiai on mortality of rainbow trout juveniles and average body mass and on the increase of relative body mass has not changed. In 1989–1996, in all tested waste water of INPP channels a deterioration of the physiological state of embryos and larvae has been detected.

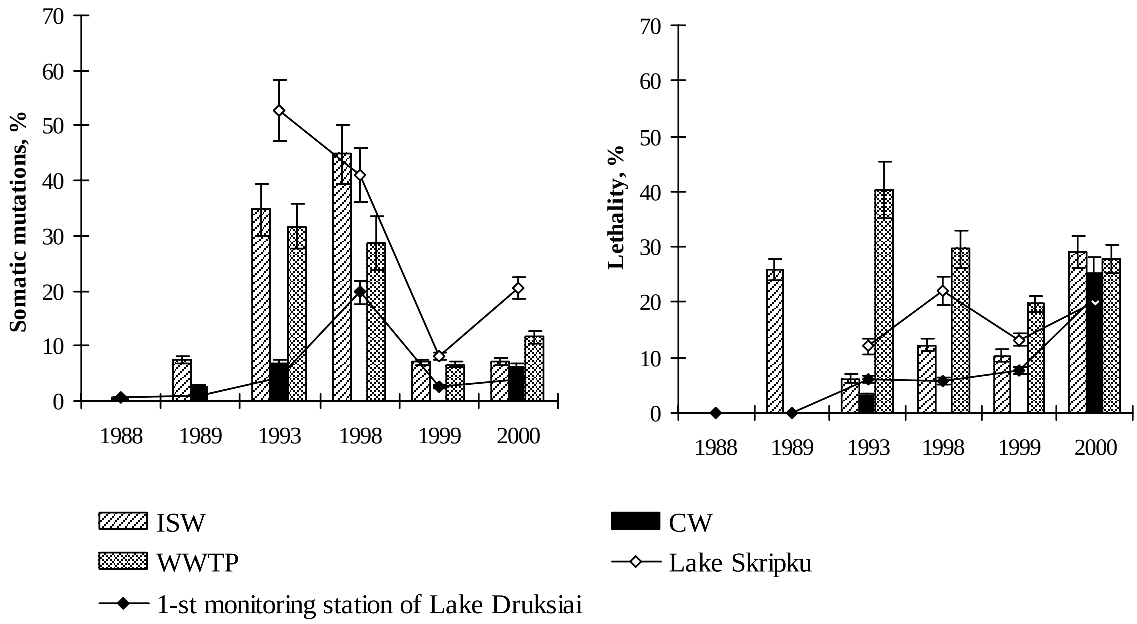


Figure 7.1-34. Genotoxic effect of bottom sediments of ISW and CW waste water channels, channel of the waste water (after treatment) of Visaginas municipal waste water treatment plant (WWTP) and Lake Druksiai and Skripku on *Tradescantia* (spiderwort) during 1988–2000.

It has been estimated that in 1996–2000 and 2007 the toxic impact of bottom sediments of waste water channels of INPP and of Visaginas municipal WWTP to garden-cress ranged from strong to weak toxic or non-toxic. For spiderwort the genotoxicity of tested bottom sediments ranged from medium to strong (Figure 7.1-34). Bottom sediments of all analyzed monitoring stations of Lake Druksiai caused a higher than 1 % amount of somatic mutations in the stamen hair (SH) system of spiderwort, and it is considered (*Shevchenko, Pomerenceva, 1985*) that 1 % of somatic mutations that occurred in the SH system of spiderwort revealed genetic changes, which may cause extinction of sensitive plant species.

Water of INPP discharge channels and Lake Druksiai and bottom sediments usually caused colourless and morphological, and only rarely (and only till 1993), pink mutations, which as it is thought (*Sparrow et al., 1972; Ichikawa, 1992; Marciulioniene et al., 1996*) generally occurs due to impact of radiation. Therefore, the scientist have concluded that genotoxicity of water and bottom sediments of INPP discharge channels and Lake Druksiai was caused not by ionizing radiation, but more by the impact of the mixture of non-radioactive and radioactive substances present in the waste water of INPP.

Long-term investigations show that water and bottom sediments of Lake Druksiai were most toxic in 1993–1998. Most usual radioactive and chemical pollution of the Lake Druksiai was detected in the period from 1988–1993, and the most evident genetic changes in biological tests were recorded in 1993.

7.1.1.9 Water temperature monitoring

The regulation in force “Standard Limits of Permissible Warming of Lake Druksiai Water and Methodology for Temperature Control” (*LAND 7-95/M-02*) has been prepared for protection of the Lake Druksiai ecosystem, i.e. trophic regimen, water quality and fauna. According to this regulation the following standard limits have been established for Lake Druksiai:

- Water surface temperature shall not exceed 28 °C in a water area not less than 80 % of the total area of the lake (*Clause 1.1 of LAND 7-95/M-02*);
- In the cooling water inlet channel at a depth of 10 centimetres the temperature shall be less than 24.5 °C (*Clause 1.2 of LAND 7-95/M-02*);
- Operation of two INPP units shall not be limited in the cool period of the year (from October 1 till April 30) (*Clause 2 of LAND 7-95/M-02*).

In the methodological part of this regulation there are the following requirements:

- Temperature of Lake Druksiai water is controlled by always measuring the temperature of water surface in the flow of the INPP cooling water inlet channel in the same point;
- Water surface temperature shall be measured at a depth of 10 centimetres each day from 10 till 12 o’clock;
- Temperature is measured by mercurial thermometer, standard error of which is ±0.2 °C. If measuring is performed using other devices, the standard error of them shall not exceed ±0.2 °C;
- The measured lake water temperature shall be recorded in a special register.

According to existing practice and Ignalina NPP Environmental Monitoring Program the INPP is measuring the temperature of:

- Inlet channel – every day, one measurement a day from 10:00 till 12:00 (designation: Intake near the Building 120/1, according to attachment 1 of the Environmental Monitoring Program);

- All outlet channels (namely RSR-1,2, Intake, RSR-3, Release, RSR SFSF, , according to attachment 1 of the Environmental Monitoring Program) every fortnight; Lake Druksiai – 3 times per year (e.g. see Table 7.1–27 1-3, measurement locations are shown in Figure 7.1-35);
- Lake Druksiai, a lot of measurements over the area at the day when inlet channel water is more than 24.5 °C, usually 1–3 times per year, according to LAND 7-95/M-02.

If the standard limits of temperature of water in the inlet channel are exceeded, i.e. temperature exceeds 28 °C in 20 % of the lake surface, there must be a reduction of power production and discharge of cooling waters.

Table 7.1–27. Water temperatures of Lake Druksiai.

Measurement date	Water temperature (°C) at the measuring positions 1, 2, 3, 4 and 6 shown on Figure 7.1-35				
	1	2	3	4	6
May 30, 2005	18.1	19.2	15.8	25.4	19.1
August 1, 2005	23.1	25.4	21.9	30.3	22.6
September 19, 2005	16.8	17.3	16.0	16.1	16.0
May 10, 2006	12.3	14.5	15.2	22.9	15.9
July 10, 2006	27.6	26.8	27.8	33.2	26.3
September 25, 2006	17.9	20.0	17.1	21.0	16.6
May 5, 2007	24.1	23.0	21.3	27.2	21.8
July 30, 2007	20.1	19.4	18.8	27.9	19.6
September 24, 2007	14.2	17.3	13.5	14.4	13.4

During the operation of one Ignalina NPP unit the heat load to Lake Druksiai is more than 0.06 kW/m^2 (i.e. the amount of heat transmitted to the lake per month is 8700 TJ) and during the operation of two INPP units it is 0.11 kW/m^2. Cooling water impact on lake temperature can be seen from Table 7.1–27 and Figure 7.1-35. Water temperature at the location 4 of Lake Druksiai, where the cooling water is discharged, is approximately 4–7 °C higher than at location 2, where the cooling water is taken from.

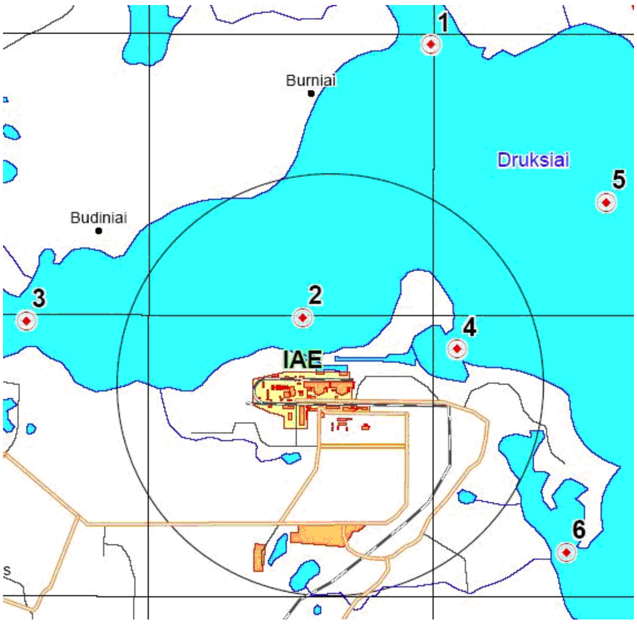


Figure 7.1-35. Locations for investigation of the “zero” background in Lake Druksiai (location 5 has not been investigated in recent years because of close proximity to the state border with Republic of Belarus).

The water temperature data covers 18 years (1981–1998), under wide range of different weather and INPP capacity conditions. The survey on surface temperature has been made over 150 times, at 12-90 sites (depending on the season) (Figure 7.1-36). Digital maps have been developed interpolating the point data of the lake surface temperature.

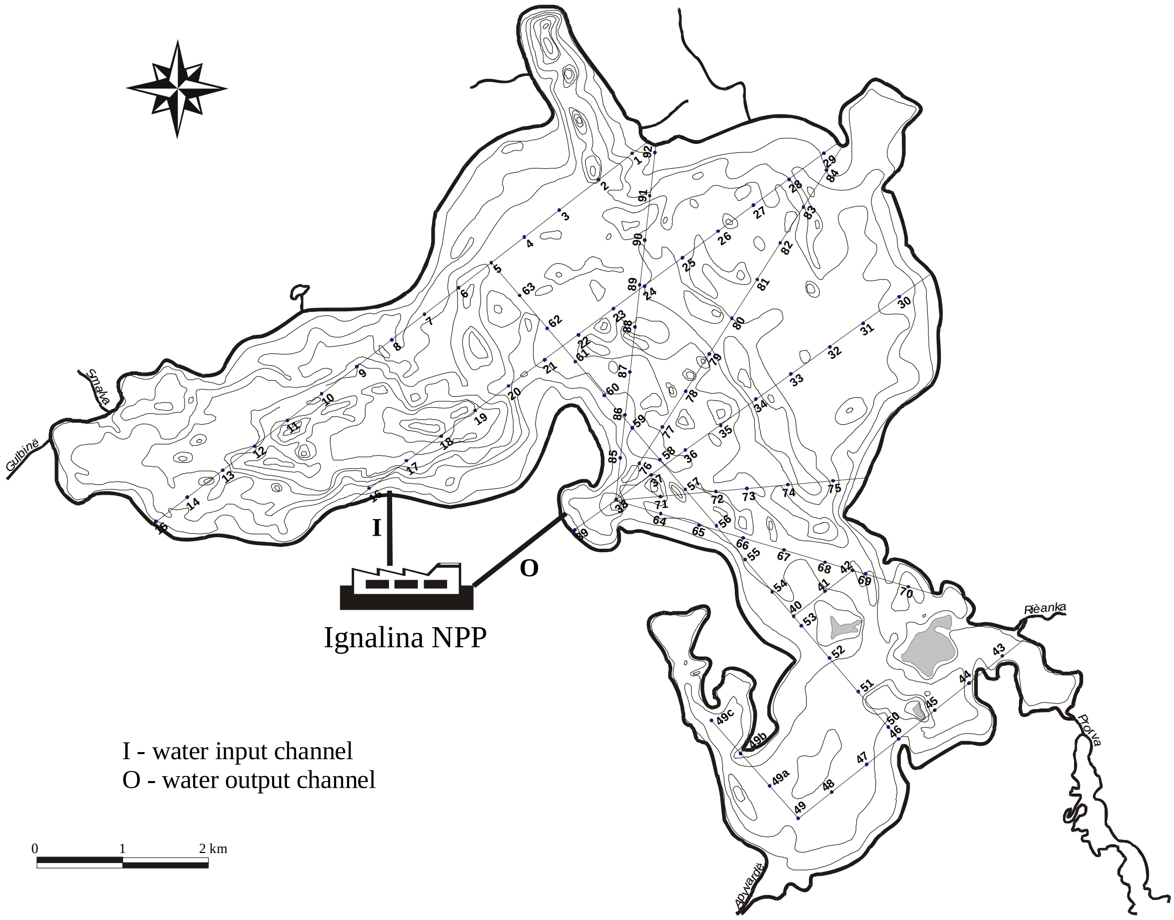


Figure 7.1-36. The scheme of the lake water temperature measurement sites and INPP location.

The surface temperature natural distribution in summer before the INPP was taken into operation (August 3, 1983) is presented in Figure 7.1-37. Since the wind was weak (0.75 m/s), its impact can be ignored and the lake temperature can be considered evenly distributed according to the lake bathymetry, shape and tributaries' inflows. The main determinant for water surface layer temperature was the air temperature.

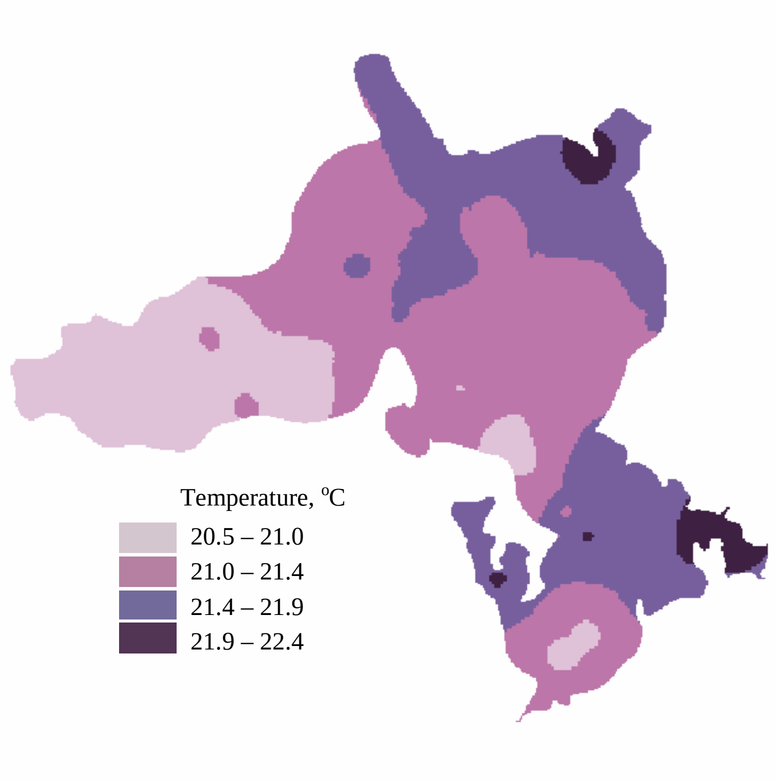


Figure 7.1-37. The surface temperature natural distribution in the lake (August 3, 1983; before the INPP was taken into operation).

A large area of lake surface allows a wind to run up. Strong winds change the temperature distribution forcing the warm surface water to move downwind (Figure 7.1-38).

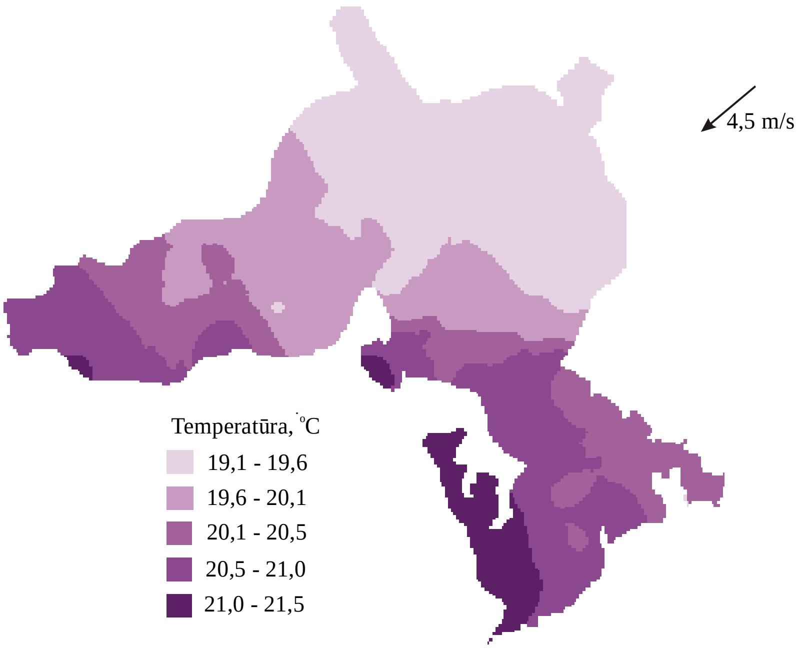


Figure 7.1-38. The natural distribution of surface temperature in Lake Driuksiai (July 9, 1981; before the INPP was taken into operation).

The first unit of the INPP unit was taken into operation in 1984 and since 1988 both units were operating. Their total capacity did usually not exceed 2 500 MW. Approximately 80 m^3/s of lake water is used for cooling one INPP unit. For two units the cooling water demand was 135 m^3/s in winter and 160 m^3/s in summer. Water inside the condensers is heated by 9-12 ºC (compared to the input water temperature). Water temperature cools down by 2–3 ºC in the output channels *(Janukeniene, Jakubauskas 1992)*. Figure 7.1-39 presents the thermal state of the lake on August 5, 1984. INPP was operating with 788 MW load. The weather on the investigation day was fine, without wind. Therefore it can be seen how the structure of the lake thermal field was influenced not only by natural factors but also by the cooling water discharge of the INPP. The map shows that the temperature fluctuated from 22.1 ºC in the western (deepest) part of the lake to 27.9 ºC within 1–1.5 km radius from the power plant discharge channel. According to Gailiusis and Virbickas (*1995*) the naturally highest surface temperature in Lake Druksiai fluctuates from 20.4 to 25.5 °C. Hence the lake was heated over the natural maximum temperature. The area with temperature higher than 25.5 °C reached 17 % of total lake surface area. The heated water spread evenly throughout the lake surface, because the wind speed during this period was insignificant.

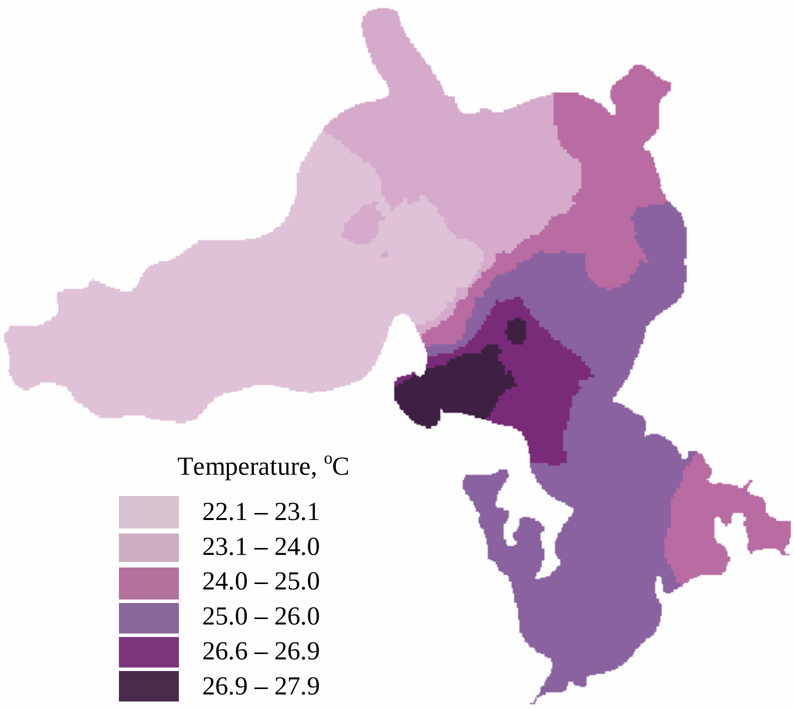


Figure 7.1-39. The distribution of surface temperatures with INPP operation effect of 788 MW. (August 5, 1984).

The response of the lake to the two units operating at a high air temperature (25.9 ºC) and still wind condition is shown in Figure 7.1-40. The average surface temperature reached 30.1 ºC and the maximum temperature 36.6 ºC. This is the highest recorded temperature rise (per area) in the lake (Table 7.1–28). The thermal state of the lake was determined by a combination of unfavourable conditions of low wind and high air temperature. During that day, in 86 % of the area the temperature was higher than 28 °C and in 100 % it was higher than 25.5 °C.

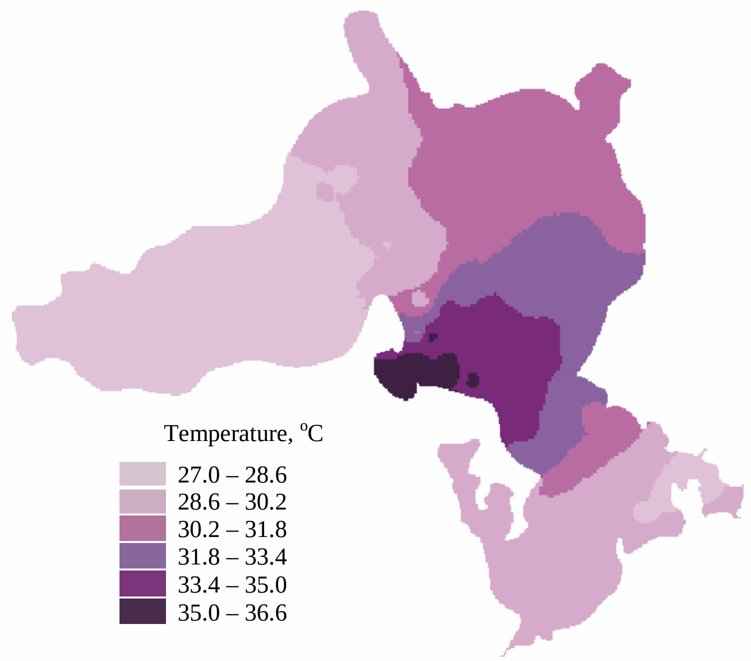


Figure 7.1-40. The lake-cooler state (July 15, 1988); INPP output 2 447 MW.

The form of the hot water field on windy days show, that southern and eastern winds are unfavourable for cooling. The winds from the north and the west turn the stream of hot water to the southern part of the lake and increase cooling.

Table 7.1–28. The database records of the highest overheating of the each year.

Date	Lake surface temperature, °C			% of surface over		INPP electrical capacity, MW	Air tempe-rature, °C
	Highest in outlet (point no. 39)	Lowest	Average	>25.5 °C	>28 °C		
August 9, 1984	30.3	23.9	25.4	50	6	796	21.4
June 26, 1985	32.5	21.5	23.5	12	5	1505	19.8
June 18, 1986	33.4	23.6	26.8	66	**24**	1490	25.5
June 23, 1987	27.4	19.6	21.7	3	0	1051	21.1
July 15, 1988	36.6	27.0	30.1	**100**	**86**	2447	25.9
July 12, 1989	32.5	23.1	25.3	34	8	1264	22.5
August 10, 1990	32.6	20.3	21.6	8	4	2500	18.5
August 4, 1991	35.4	23.6	25.5	31	11	1296	25.8
June 1, 1992	30.5	19.2	21.5	11	2	1243	23.6
July 19, 1993	27.3	20.6	21.7	1	0	778	21.8
August 5, 1994	31.1	26.3	27.3	**100**	**38**	759	25.0
August 22, 1995	32.8	24.0	24.4	41	11	1293	21.5
August 23, 1996	35.0	21.3	24.0	13	7	1272	25.5
July 6, 1997	32.5	22.6	24.1	4	3	747	22.1
June 6, 1998	32.1	21.7	22.7	25	17	1306	24.0

The highest surface temperatures are reached during the warm summer months. The cooling water discharge has increased the average monthly temperature of the lake by 3–4 degrees (Figure 7.1-41).

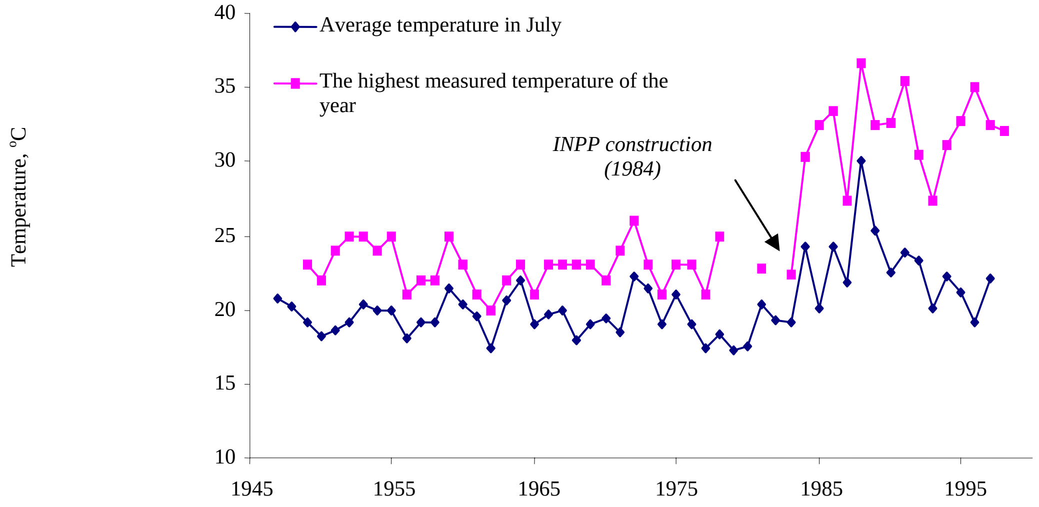


Figure 7.1-41. Surface water temperatures of Lake Druksiai before and after Ignalina NPP construction.

Comparative analysis of average annual temperature of the vertical water layers in Lake Druksiai and some natural lakes for the period 1985–1989 has shown that in Druksiai water temperature at 10 m depth has risen by 4.2 °C and at 30 m depth by 2.2 ^{o}C. Evaluation of the anthropogenic impact on Lake Druksiai is complicated, because the rise of lake bottom temperature is also being observed in other Lithuanian lakes (Dusia, Plateliai, Tauragnas) (*Pernaraviciute, 1998*).

7.1.2 Assessment of impacts of raw water consumption and waste waters

7.1.2.1 Raw water consumption

Potable water supply for the present Ignalina NPP is outsourced to the state (Ministry of Economy) owned Visaginas Energija, which serves also the town of Visaginas. Groundwater is used as raw water and it requires only a simple treatment of aeration and filtration to remove excessive iron. The total water production capacity is 31 000 m^3/d, but as one NPP unit has already been closed and a drastic water consumption reduction has taken place in Lithuania, the present capacity in use is only about 10 000 m^3/d, and the daily average output about 6 900 m^3/d. The treated water storage tanks have a capacity of 12 000 m^3, which provides for adequate stand-by supply volume. The potable water supplier has adequate capacity and existing pipeline network to supply all potable water required at the new NPP also.

At the new NPP, potable water is required both for household purposes (e.g. drinking, showers, toilets) and for production of the process water. The potable water demand depends on size of the power plant and the project stage (Table 7.1–29).

During the construction of the plant household water consumption will be at its highest, depending, however, on the phase of construction and the number of workers at that time. The total consumption will, however, be approximately same or slightly less than during the operation period since no process water is needed. The required potable water supply capacity is 650 m^3/d for 1 700 MW power plant and 1 300 m^3/d for 3 400 power plant.

Table 7.1–29. Potable water demand for two plant alternatives.

	Average daily flow m^3/d	
	Alt 1 ≤1 700 MW	Alt 2 ≤3 400 MW
Potable water demand		
Construction period	300-450	600-750
Operation period, for household use	150	300
Operation period, for process water prod.	400-500	800-1 000
Annual maintenance, for household use	250	250
Annual maintenance, for process water	200	600-700
Required potable water supply capacity	650	1300

The quality of the potable water is suitable for household needs and no additional treatment at the NPP is required. For process purposes, however, the water must be demineralised ("removal of salts") in a demineralisation plant at the NPP site. The demineralisation plant will have a capacity of 400-700 m^3/d depending on size and type of the power plant.

In addition to the potable water also water from Lake Druksiai will be used for purposes not requiring such a high quality. These comprise service water and fire protection water. Service water is used for some household purposes, like cleaning and washing floors and surfaces, and for cleaning the cooling water screens and filters (see Section 7.1.2.3). Water from the lake is also used in case of fires. Sufficient supply of fire water is guaranteed with an adequate pumping station and water basins at the NPP site.

7.1.2.2 Waste waters

In the following the non-radioactive waters are described. Treatment of the waste waters originating from the controlled area, i.e. potentially radioactive waters, is described in Section 6.2.2.

Household waste waters

Household waste water treatment for the present Ignalina NPP is outsourced to the state owned company (Ministry of Economy) Visaginas Energija, which serves also the town of Visaginas. The same company will be responsible for household waste water treatment also for the new NPP.

Visaginas Energija operates a municipal wastewater treatment plant. The plant capacity is 21 000 m^3/d, but it is in need of rehabilitation. A reconstruction project has started in May 2008 by signing the construction contract. The capacity of the new Visaginas waste water treatment plant (hereinafter – WWTP) will be 5500 m^3/d. The new WWTP will be equipped with intensive biological waste water treatment installations – activated sludge plant with automated process control, enabling to maintain an optimal ratio of activated sludge and pollutants. The new WWTP will reduce discharges of phosphorus and nitrogen several times, and it will be able to meet the current Lithuanian and EU effluent standards. The reconstruction project is financed by the Lithuanian state and EU Cohesion Fund and it is expected to be completed by 2010.

Table 7.1–30 gives the estimated maximum household sewage discharge and pollutant loads after treatment during NPP operation.

Table 7.1–30. The household waste water amounts per day and yearly pollutant loads after treatment in the new WWTP.

Parameter	Alt. 1 ≤1700 MW	Alt. 2 ≤3400MW
Flow m^3/d	150	300
BOD_5 at 25 mgO_2/l, kg BOD_5/year	1 370	2 740
COD at 125 mgO_2/l, kg O_2/year	6 850	13 700
Total suspended solids at 35 mg/l, kg TSS/year	1 920	3 830
Total phosphorus at 2 mgP/l, kg P/year	110	220
Total nitrogen at 15 mg/l, kg N/year	820	1 640

The loads from the new NPP will represent either 4 or 8 % of the loads from the municipality of Visaginas. The effluent is discharged through a pond named Skripku to Lake Druksiai. Reduced concentrations of BDS_5, nitrates and phosphorus in the discharges will improve Lake Druksiai water quality.

Process water

The waste waters from the process water production include regeneration effluents and reject water. Regeneration effluents are generated when the ion-exchange resins are treated with strong acid (sulphuric acid, H_2SO_4) and base (sodium hydroxide, NaOH). Approximately 5–10 % of the water flow through the process water treatment will form reject water. These effluents contain mainly cations (e.g. sulphates) and anions (e.g. iron, sodium) originating from the raw water and the treatment. Both the regeneration effluents and the reject are led to a neutralisation basin where the pH will be brought to a range of 5–9 before discharging to the lake. The discharged waste waters mainly contain minerals from the neutralisation. After the neutralisation basin the process water will be released into Lake Druksiai. Exact release location will be chosen in Technical Design.

Approximately 28–56 tonnes of sulphuric acid and 50–100 tonnes of sodium hydroxide (50 % concentration) will be used annually in the process water neutralisation. If the new power plant will be of pressurised water type (PWR), it will also cause a boron load of approximately 2–4 tonnes per year due to the use of this chemical in the process water. No other chemicals used for process water production will be discharged to the lake.

Surface water

All surface water from the NPP site will be channelled through the wells of oil detection and surface water drains to the sedimentary basin. The basin will be equipped with a system of automatic oil detection.

Surface water flows that might contain oil (e.g., rain water from the secondary oil reservoir basins and sites, contaminated by oil products) will be transferred through the oil separators before redirecting them to the sedimentary basin and subsequently releasing into the lake. The reservoir with the oil separator will collect oil waste, which will be transmitted to hazardous waste management companies for utilization or disposal. Water from the oil separator will be discharged to surface water drains. Location of surface water release is marked in Figure 7.1-23.

7.1.2.3 Cooling water

Lake Druksiai serves as the source of cooling water. The main part of the cooling water is needed for cooling the condensers and a minor part for various rotating devices and some other components. Cooling water is pumped to the power plant via a cooling water intake structure in Lake Druksiai.

Cooling water does not need any treatment. However, coarse organic and other material carried by the water (such as plants, fish, rubbish etc.) are sieved at the cooling water intake by a coarse bar screen and closer to the power plant by denser screens. The screens are regularly washed with lake water to remove the collected material. The collected material is treated according to solid waste management regulations and procedures.

From the condenser the warmed cooling water is led back to Lake Druksiai along the cooling water outlet channel.

When passing through the cooling system of the NPP, the quality of cooling water does not normally change in any other way than that the temperature rises approximately 9 – 11 degrees. However, under certain conditions so called antifouling chemicals like hypochlorites may need to be added to cooling water to prevent biofouling. Biofouling means that bacteria, algae, plants and animals like mussels grow on the surfaces of the cooling system in amounts that would harm the effective functioning of the system. The amount of antifouling chemicals used and quality of the discharged water will be monitored and controlled according to the regulations.

The need of cooling water depends on the produced power, technical features of the plant type (the core thermal output and the gross electrical output differ a little in different NPP types) and on the temperature rise in the condenser. Approximate cooling water needs for different power levels are given in Table 7.1–31. Conservatively it was assumed that 65 % of the thermal energy produced in the reactor has to be discharged to the environment (in reality this will be 62-63 %). Therefore as a starting point an environmentally acceptable temperature rise of approximately 10 °C was assumed. This means that to discharge excess heat from 3400 MW_e reactors approximately 160 m^3/s water flow is necessary. This is calculated based on the thermal capacity of water (nature constant). For example, if 80 m^3/s water flow is needed to cool 3400 MW_e, the temperature rise would be 20 °C.

In the table (Table 7.1–31) the thermal load ($P_{Released}$) is presented for different energy production levels ($P_{Electrical}$).

Table 7.1–31. Energy production levels ($P_{Electrical}$, P_{Total} and $P_{Released}$) and cooling water demand.

$P_{Electrical}$ MW	P_{Total} MW	$P_{Released}$ MW	Flow m^3/s
750	2140	1390	35
1200	3430	2230	55
1400	4000	2600	65
1700	4860	3160	80
2400	6860	4460	110
2800	8000	5200	130
3400	9710	6310	160

Cooling water demand presented in Table 7.1–31 does not depend on the cooling water temperature (does not vary between winter and summer). The cooling water demand has been estimated conservatively and this estimation is maximal.

The existing cooling water structures have a design capacity of 170 m^3/s. As the maximum need for the new NPP is estimated to be 160 m^3/s, the capacity of the existing structures will be adequate also for the new NPP.

During the spent nuclear fuel removal from the reactor core and storage pools of the existing NPP only one cooling water pump (*IAE letter No. 109-4859* (12-14, dated 2007-08-27)) will be needed. This phase is preliminarily planned to be finished before the end of 2015. The cooling water need during that period is very small (about 1.7 m^3/s) compared to cooling water need of the new NPP. Thus there is no discrepancy in using the same inlet channel for the NNPP.

7.1.2.4 Impacts of waste water load on water quality

Household waste water

Lake Druksiai has undergone an eutrophication development during the last decades and this unfavourable development is still continuing. Household waste waters from Visaginas waste water treatment plant (WWTP) have been and are still forming the majority of nutrient load to the lake. Improvement of water treatment has led to decrease in nitrogen load but the phosphorus load has not decreased.

At present approximately 80 % of the total phosphorus load and 55 % of the total nitrogen load to Lake Druksiai comes from the Visaginas WWTP. The new WWTP will decrease the total annual load of phosphorus by 60 % and nitrogen by 40 % compared to the present. The nutrient load from the new NPP will comprise only 4 to 8 % of the total nutrient load to be discharged from the Visaginas new WWTP.

The new WWTP is considered as an environmentally best option for treatment of the household waste waters from the NNPP. The nutrient load from the new NPP to Lake Druksiai will be smaller than the present load from INPP due to the new WWTP. The nutrient load from the NNPP will be small compared to the total load to Lake Druksiai coming from the other sources (e.g. Visaginas municipality and natural runoff). Thus the impacts of the new NPP on lake water quality and eutrophication can be considered insignificant and the proposed treatment at the new WWTP adequate.

Process waste water

Process waste waters discharged to the lake contain dissolved salts which are found in small amounts also naturally in lake water. The dissolved salts combined with increased evaporation rate can lead to increase in lake water salinity (which is in lakes often measured as a concentration of total dissolved solids (TDS)).

The process water production at the new NPP will produce approximately 180–450 kg of salts per day which are discharged to the lake. Impacts of the process water to the lake salinity were evaluated based on the amount of salts discharged and the water balance (inflow, evaporation and outflow). According to this rough estimation salt addition would increase the TDS in lake water by 0.1–0.34 mg/l per year. During the plant's operation period (60 years) the total increase would be approximately 6–20.4 mg/l if calculated linearly. This evaluation is, however, very rough and possibly an overestimate, as it takes only the outflow from the lake into account as a way to decrease the salt content. In reality, however, dissolved salts are removed from the water also by organisms, chemical reactions and eventually sedimentation to the lake bottom.

On the other hand, the dissolved salts are probably not distributed evenly to the whole lake volume. The concentration of TDS can rise higher than assumed especially if the process waste waters are not well mixed with the lake water when discharged. The denser and heavier process water may accumulate to water layers close to the bottom. Theoretically, this can intensify lake stratification and decrease water circulation. This can then lead to decrease of oxygen concentration and intensification of sulphate reduction and nutrient release from the bottom in the deep water layers.

During the operation of Ignalina NPP the TDS concentration has risen from 224 mg/l to 264 mg/l. It is clear that the TDS has not increased as much as was expected before the operation started. This is suggested to be mainly due to the growth of zebra mussels and macrophytes which decrease the HCO_3^- and Ca_2^+ concentrations in water. The observed increase in TDS concentration roughly corresponds to an increase from 0.022 to 0.026 % in salinity.

The new NPP will not increase the amount of salts discharged compared to the present situation. The increase in TDS has so far been slow and the new NPP is not expected to significantly change this. As most of the fresh water species can live in salinities lower than 0.5 %, the salinity is not expected to increase to levels harmful for organisms.

Boron is an essential micronutrient but toxic in high concentrations. In case the new NPP will be a pressurised type reactor (PWR) also boron will be released to the environment as it is used in the process. According to WHO (*WHO, 1998*), the environmental no-effect concentration for boron is 1 mg/litre. The concentration of boron is not expected to rise over this value during the operative time (60 years) of the new NPP. Thus no harmful impacts are expected.

As the concentrations of TDS or single ion (e.g. boron, chloride) can, however, rise on some parts of the lake, they should be continuously monitored. If the concentrations are rising to levels causing directly or indirectly adverse effects on the lake ecosystem, additional treatment methods of process waste waters, like evaporation, should be considered.

7.1.2.5 Summary of the water consumption and treatment

The detailed information about the planned water consumption amounts and treatment are summarised in Table 7.1–32, Table 7.1–33, Table 7.1–34, Table 7.1–35 and Table 7.1–36.

Table 7.1–32. Predicted water intake and consumption in two alternative power production options.

No	Water source	Maximum planned water intake capacity			Activity with water consumption	Maximum planned water consumption amount for each activity			Planned water loss	Water amount planned to be delivered to other consumers
		m^3/y	m^3/d	m^3/h		m^3/y*	m^3/d	m^3/h	m^3/y	
ALTERNATIVE ≤1700 MW										
1	Lake Druksiai	$29x10^8$	$86x10^5$	360 000	Cooling water	$23x10^8$	$69x10^5$	288000	Insignificant	No
2	The network of Visaginas Municipality	60 000	1 000	70	Household consumption during normal operation	54 750	150	20	Insignificant	No
3	The network of Visaginas Municipality	8 000	1 000	70	Household consumption during annual maintenance	7 500	250	30	Insignificant	No
4	Lake Druksiai	645 000	2 000	180	Service water (rinsing the cooling water screens etc.)	640000	1 900	160	Insignificant	No
5	The network of Visaginas Municipality	170 000	500	30	Process water production	167 500	500	30	Insignificant	No
ALTERNATIVE ≤3400 MW										
1	Lake Druksiai	$52x10^8$	$16x10^6$	648000	Cooling water	$46 x10^8$	$14x10^6$	576 000	Insignificant	No
2	The network of Visaginas Municipality	120 000	1 000	70	Household consumption during normal operation	109 500	300	40	Insignificant	No
3	The network of Visaginas Municipality	8 000	1 000	70	Household consumption during annual maintenance	7 500	250	30	Insignificant	No
4	Lake Druksiai	810 000	2 600	240	Service water (rinsing the cooling water screens etc.)	804000	2 400	200	Insignificant	No
5	The network of Visaginas Municipality	340 000	1 000	70	Process water production	335 000	1 000	60	Insignificant	No

* - water amount in this column is lower than presented in column „Maximum planned water intake capacity“ due to some insignificant losses during water intake

Table 7.1–33. Information about wastewater sources and dischargers.

DischargerNo.	Wastewater source	Discharger type/technical data	Description of discharge area	Maximum foreseen effluent amount			
				m^3/s	m^3/h	m^3/d	m^3/y
ALTERNATIVE ≤1700 MW							
2**	Reject concentrate from process water production	Discharge will be chosen during Technical Design	Lake Druksiai	0.002	5	100	33500
4	Household waste water	Waste water treatment plant of Visaginas	WWTP	0.010	15	150	55000
2.1**	Service water	Discharge will be chosen during Technical Design	Lake Druksiai	0.1	160	1900	640000
3	Cooling water	Discharge will be chosen during Technical Design	Lake Druksiai	80	288000	$69x10^5$	$23x10^8$
PLK-1,2 PLK-3*	Surface water	Discharge will be chosen during Technical Design	Lake Druksiai	-	-	-	$9.5x10^6$
ALTERNATIVE ≤3400 MW							
2**	Reject concentrate from process water production	Discharge will be chosen during Technical Design	Lake Druksiai	0.004	10	200	67000
4	Household waste water	Waste water treatment plant of Visaginas	WWTP	0.018	30	300	109500
2.1**	Service water	Discharge will be chosen during Technical Design	Lake Druksiai	0.1	200	2 400	804000
3	Cooling water	Discharge will be chosen during Technical Design	Lake Druksiai	160	576000	$14x10^6$	$46\ x10^8$
PLK-1,2 PLK-3*	Surface water	Discharge will be chosen during Technical Design	Lake Druksiai	-	-	-	$9.5x10^6$

*- Discharger numbering is marked in Figure 7.1-17
**- Exact location of process water discharger will be chosen in Technical Design

Table 7.1–34. Pollution load planned to be discharged/ forecasted pollution of environment.

Pollutant name		Maximum forecasted pollution of effluent before treatment				Maximum permissible and actual forecasted pollution of planned effluents/ planned pollution of the environment								Foreseen purification effectiveness. %
		inst. [1], mg/l	aver. [2] mg/l	t/d [3]	t/y	MPC inst. [4], mg/l	planned inst. [5], mg/l	MPC aver. [6], mg/l	planned aver. [7], mg/l	MPC 24 h [8], t/d	planned 24 h [9], t/d	MPC annul. [10], t/y	planned annul. [11], t/y	
Surface water No. PLK-1,2 PLK-3	Suspended materials	-	-	-	-	50	50	30	30	-	-	285	285	-
	Oil products	-	-	-	-	7.0	7.0	5.0	5.0	-	-	47.5	47.5	70-90
	BOC_5	-	-	-	-	50	50	25	25	-	-	238	238	-
ALTERNATIVE ≤1700 MW														
Process wastewater No. 2	BOC_5	n/a	250	0.025	8.38	n/a	n/a	25	20	0.003	0.002	0.838	0.670	≤90
	N_{total}	n/a	40	0.004	1.34	n/a	n/a	15	12	0.002	0.001	0.503	0.402	70
	P_{total}	n/a	7	0.0007	0.235	n/a	n/a	2	1.5	0.0002	0.0002	0.067	0.050	75
	COD	n/a	1200	0.120	40.2	n/a	n/a	125	120	0.013	0.012	4.187	4.02	70-90
Process wastewater No. 2.1	BOC_5	n/a	250	0.475	160	n/a	n/a	25	20	0.048	0.038	16.0	12.8	92
	N_{total}	n/a	40	0.076	25.6	n/a	n/a	15	12	0.029	0.023	9.6	7.68	70
	P_{total}	n/a	7	0.013	4.48	n/a	n/a	2	1.5	0.004	0.003	1.28	0.96	75
	COD	n/a	1200	2.28	768	n/a	n/a	125	120	0.238	0.228	80.0	76.8	70-90
ALTERNATIVE ≤3400 MW														
Process wastewater No. 2	BOC_5	n/a	250	0.05	167.5	n/a	n/a	25	20	0.05	0.004	1.68	1.34	≤90
	N_{total}	n/a	40	0.008	2.68	n/a	n/a	15	12	0.003	0.002	1.01	0.80	70
	P_{total}	n/a	7	0.0014	0.469	n/a	n/a	2	1.5	0.0004	0.0003	0.134	0.100	75
	COD	n/a	1200	0.240	80.4	n/a	n/a	125	120	0.025	0.024	8.38	8.04	70-90

Pollutant name		Maximum forecasted pollution of effluent before treatment				Maximum permissible and actual forecasted pollution of planned effluents/ planned pollution of the environment								Foreseen purification effectiveness. %
		inst. [1], mg/l	aver. [2] mg/l	t/d [3]	t/y	MPC inst. [4], mg/l	planned inst. [5], mg/l	MPC aver. [6], mg/l	planned aver. [7], mg/l	MPC 24 h [8], t/d	planned 24 h [9], t/d	MPC annul. [10], t/y	planned annul. [11], t/y	
Process wastewater No. 2.1	BOC_5	n/a	250	0.6	201	n/a	n/a	25	20	0.06	0.05	20.1	16.1	≤90
	N_{total}	n/a	40	0.096	32.2	n/a	n/a	15	12	0.036	0.028	12.1	9.65	70
	P_{total}	n/a	7	0.017	5.628	n/a	n/a	2	1.5	0.005	0.004	1.61	1.21	75
	COD	n/a	1200	2.88	964.8	n/a	n/a	125	120	0.3	0.288	100.5	96.5	70-90

Since household waste water will not be released directly into environment (it will be released into the network of Visaginas waste water treatment plant) assessment of impacts is not necessary.

1 – Maximum foreseen concentration of pollutant in the instantaneous or average for 24 h effluent sample before purification;
2 – Maximum foreseen average annual concentration of pollutant in effluent before purification;
3 – Maximum foreseen amount of pollutant in effluent before purification generated during 24 hours;
4 – Maximum Permissible Concentration (MPC) in the instantaneous or average for 24 h effluent sample established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
5 – Planned concentration of pollutant in the instantaneous or average for 24 h effluent sample;
6 – Maximum permissible average annual pollutant concentration established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
7 – Planned average annual pollutant concentration;
8 – Maximum permissible average 24 hours pollutant amount established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
9 – Planned average 24 hours pollutant amount;
10 – Maximum permissible annual pollutant discharge amount established/calculated in accordance with regulations (subject to conditions for discharge into sewerage, nature of performed activity etc.);
11 – Planned annual pollutant discharge amount.

Table 7.1–35. Information on surface water body (receiver) in which the wastewater is planed to be released or which will be polluted because of proposed economic activity.

Running No.	Name of water body, category and code	Name of river watershed, watershed, subwatershed	Average discharge of dry month (95% probability), m^3/s. Area of water body, ha (volume, thousand m^3) (for dead-water body)	State of water body					
				parameter	present (background) state/MPC/impact			permissible load of water body	
					measuring unit	value		measuring unit	value
						state	MPC		
1.	Lake Druksiai, code 50040019	Daugava catchment	3622.2 ha*	BOC_7	mg/l	1.3	≤ 6	t/m	0.3

* - Area in the Republic of Lithuania territory

It is planned to release the process wastewater into Lake Druksiai. The annual load by BOC, in case of which the permissible impact on lake will not be exceeded, is calculated by formula given in the „Regulation on wastewater management“ (*State Journal, 2007, No. 110-4522*):

In accordance with the lake area:

$$\mathbf{T_n = \frac{F_{lake} * C_{lake}}{2000}}$$

$$Tn = \frac{100 * 6}{2000} = \mathbf{0.3\ t/m}$$

Here:

$\mathbf{T_n}$ – annual load BOC, N or P, in case of which the permissible impact on lake will not be exceeded, t/year;
$\mathbf{C_{lake}}$ – maximal permissible BOC, N or P (respectively) concentration in the lake (requirement for good state of the lake), (mg/l);
$\mathbf{F_{lake}}$ – lake area, ha (hectare) (if the lake area is bigger than 100 ha, it is admitted in the calculation 100 ha).

The sum of pollutant amount from all dotted sources into the lake should not exceed pollutant amount (load) calculated by given formulas.

Table 7.1–36. Means for minimisation of effluent amount and environmental pollution planned to be used.

No	Effluent source/discharger	Description of a measure and its purpose	Designed characters of the planned means	
			measure unit	value
1	Sanitary sewage treatment plant of Visaginas	Mechanical and biological treatment (reducing the load of organic and inorganic substances)	m^3/d	5 500
2	Demineralization reject concentrate	Neutralization (HCl, NaOH) (balancing the pH –value)	n/a	n/a
3	Oil separation	Grease/oil separation in weirs/basins (separation of the oily substances)	n/a	n/a

7.1.2.6 Assessment of impacts of thermal load

7.1.2.6.1 Thermal dispersion modelling

Model computations were carried out using EIA Ltd's flow model, which is a three dimensional hydrodynamic water flow model based on Navier-Stokes equations, specifically designed for modelling lakes and coastal areas (*Koponen et al., 2008*).

The bathymetry data used in the modelling was created by the company "Kumponas“, contracted by INPP (contract 1998-12-18 Nr. 401-23-3568). Research work was carried out from December 1998 till May 1999. The data contained bathymetry as depth contours at 1m intervals.

To create the digital model of the lake for the 3D-modelling the data was compared to satellite shoreline data from Google Earth. The shorelines from different sources did not match exactly, but as there is lot of reeds on shores the shoreline interpretation was seen as sufficient enough and is not seen as possible significant error source for modelling results.

To construct the model grid, first a depth model with 5 m horizontal resolution was interpolated from the isoline data. The model grid was then constructed from the depth model by averaging 5 m resolution depth data to 50 * 50 m grid boxes. Additionally the intake and outlet channel depths were set to 6.6 m and 2.9 m depths according to the information obtained from the INPP.

The model uses as an input data air temperature, air humidity, wind speed and direction, incoming solar radiation and cloudiness. Evaporation is computed in each model grid box every five minutes by using these measured values and computed lake surface temperature.

The approach in the thermal dispersion modelling has been to achieve the realistic “worst case scenario” by selecting the warmest summer of the period 1980 - 2006. In addition, a “climate change scenario“, which describes the “worst case scenario” including climate change impact has been modelled.

Selection of the modelling year was based on the average air temperature of the period 15.5 – 15.9, for years 1990-2006. Below in Figure 7.1-42 and Table 7.1–37 is shown the average summer temperatures using NCEP reanalysis 2 data, the data point used is about 70 km north from lake Druksiai, but represents a larger area. This data was considered to be accurate for selecting of the modelling period.

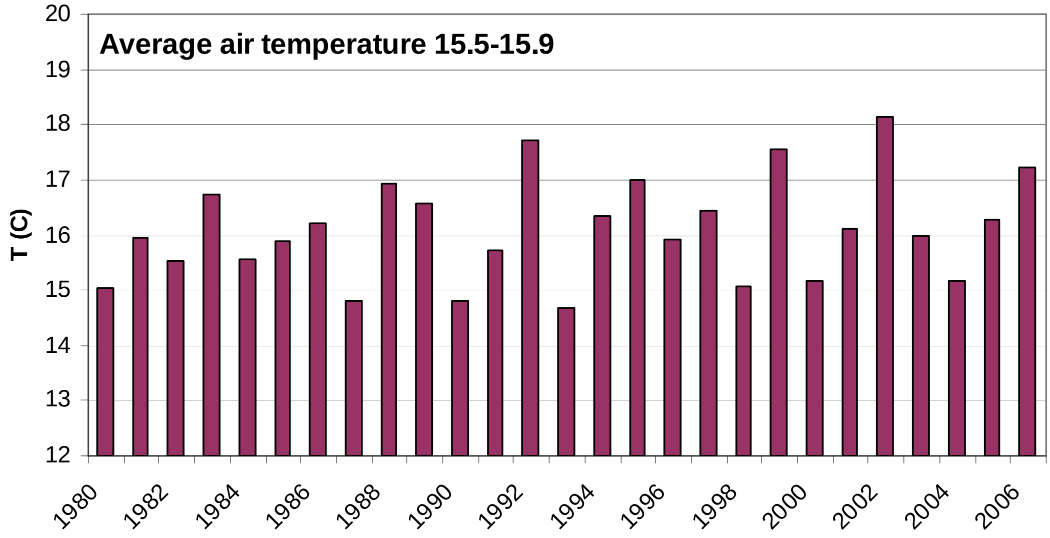


Figure 7.1-42. Average air temperature of summer period 15.5-15.9 for years 1980-2006. Data from NCEP reanalysis II point at lat 56 11' ,lon 25 15'.

Table 7.1–37. Average air temperature of summer period 15.5-15.9 for years 1980-2006. Data from NCEP reanalysis II point at lat 56 11' ,lon 25 15'.

Year	Temp (C)	Year	Temp (C)	Year	Temp (C)
1980	15.04	1990	14.80	2000	15.15
1981	15.94	1991	15.73	2001	16.10
1982	15.53	1992	17.73	2002	18.13
1983	16.74	1993	14.67	2003	15.99
1984	15.57	1994	16.33	2004	15.16
1985	15.88	1995	17.00	2005	16.28
1986	16.22	1996	15.91	2006	17.24
1987	14.82	1997	16.44		
1988	16.93	1998	15.07		
1989	16.58	1999	17.55		

Meteorological data from the Dukstas meteorological station was used in the computation. Model calibration and scenario computations were performed using summer periods of selected years. For calibration the years 1981, 1989 and 1991 were selected, using data availability, INPP usage and weather conditions as criteria. Locations of the temperature measurement points used in calibration are shown in Figure 7.1-43. The year 2002 was selected for the scenario computation, since it had the warmest summer period of the available years. Water level is constant 141.6 for all simulations. The effect of different levels of thermal load and different NNPP cooling water inlet and outlet locations on Lake Druksiai temperatures was investigated using the calibrated model. Also a lowered water level scenario was computed. Additional simulations were performed to see how change of environmental conditions would affect the results.

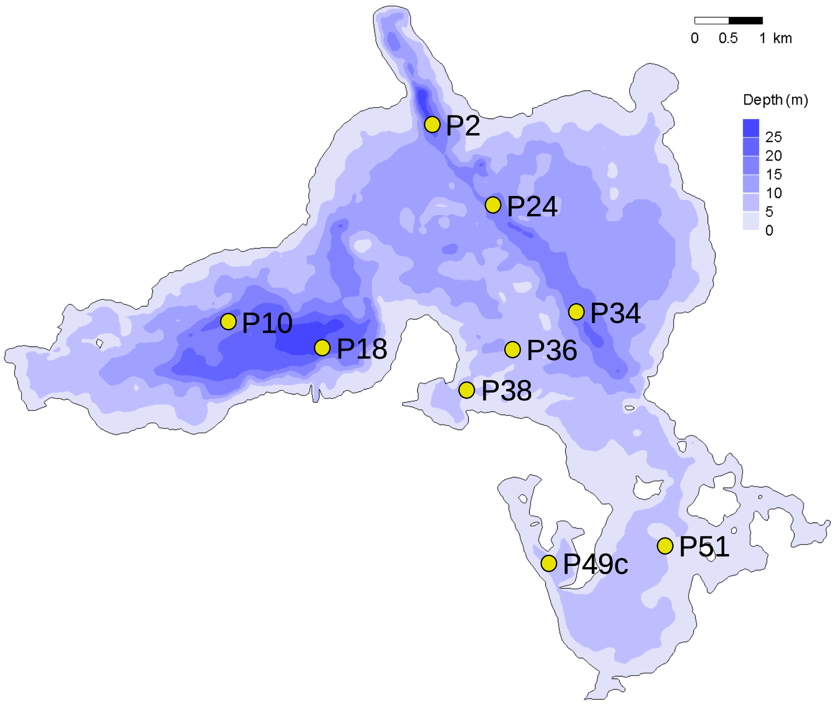


Figure 7.1-43. Location of measurement points used in model calibration.

7.1.2.6.2 Model calibration

In model calibration the computed model results are compared to conducted measurements. Different levels of model fit can be obtained depending on the used boundary condition data, meteorological data, and other model driving data accuracy, the model itself, quality of the measurement data and natural variability of the modelled natural phenomena. If differences are found the empirical and site-dependent model parameters can be adjusted in order to make the computed results fit better to the measurements.

Meteorological data

Meteorological data from the Dukstas meteorological station delivered by LHMS (Lithuanian Hydrometeorological Service) was used in the computation. Data from a site near the INPP was also available, but unfortunately not all needed time periods were available from the NPP station. Dukstas station is located at 55°31'N 26°18'E, about 17 km East-South-East from the INPP.

Model calibration and scenario computations were done using summer periods of selected years. For calibration the years 1981, 1989 and 1991 were selected, using data availability, INPP usage and weather conditions as criteria. For scenario computation the year 2002 was used, as this year had the warmest summer period of possible simulation years (criteria was average air temperature for period 1.6 – 31.8).

In the year 1981 the beginning of the summer, May, June and July, were warmer than average, while August was a somewhat bit colder than average. Wind direction distribution was typical, with most of the winds from south-west and west. However, in the model the wind direction does not affect to lake cooling much, since the wind field over the lake is uniform, e.g. the wind speed is same over most of the lake, excepting areas where near shore wind correction has been used.

Average wind speed values were between 2 and 3 m/s. The average data is shown in Figure 7.1-44.

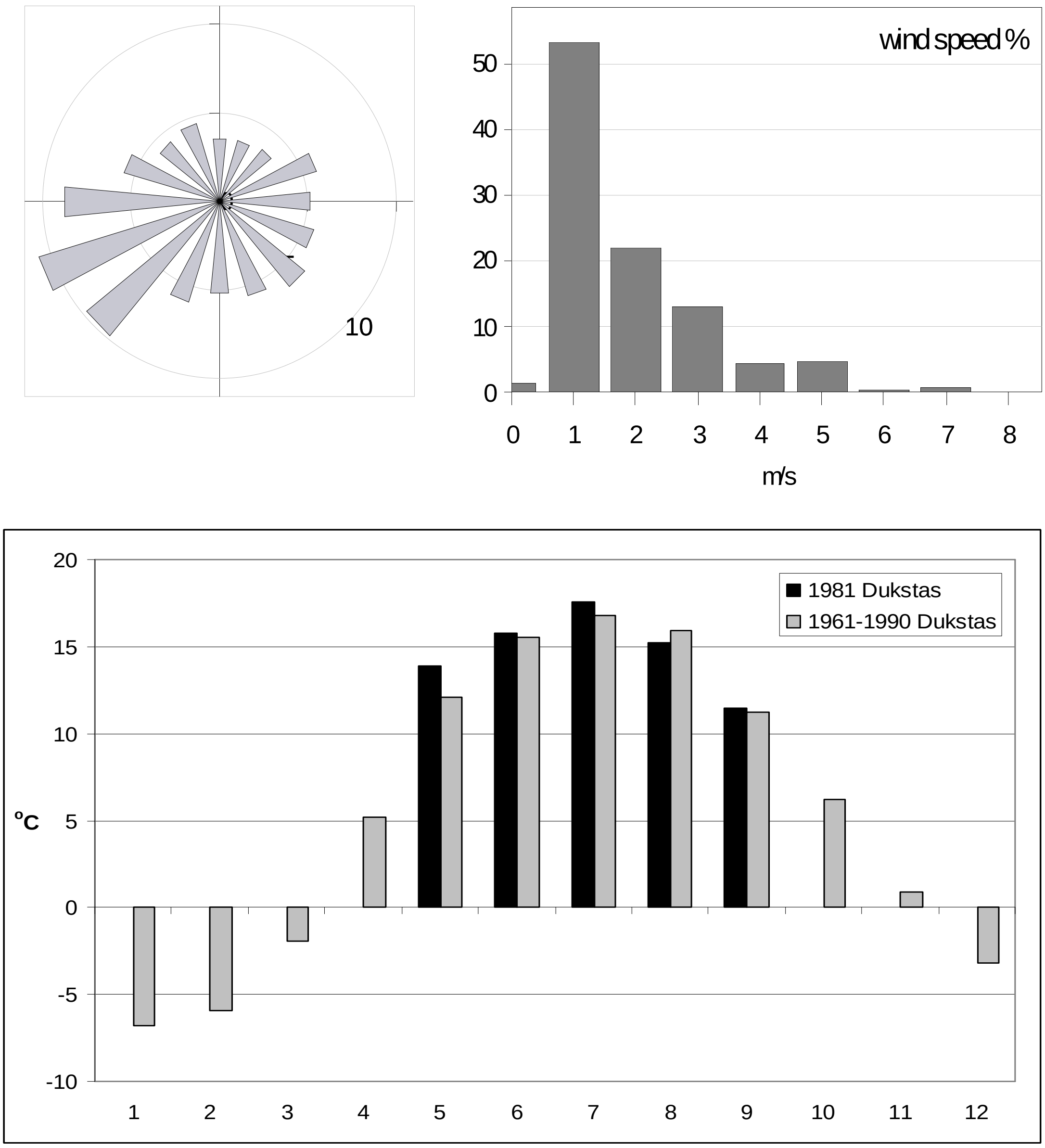


Figure 7.1-44. Wind direction and speed distributions (%) on 1.5-1.9.1981, and monthly average temperature in year 1981 at Dukstas weather station.

In the year 1989 the monthly air temperature values resemble year 1981 data. The beginning of the summer, May, June and July, was warmer than average, and August a bit colder than average. Wind direction distribution was average except for a more than average amount of North-North-West winds. Wind speeds were typical, between 2 and 3 m/s. The average data is shown in Figure 7.1-45. Wind speed distribution looks somewhat strange. This is, however, as it was in the data obtained from LHMS.

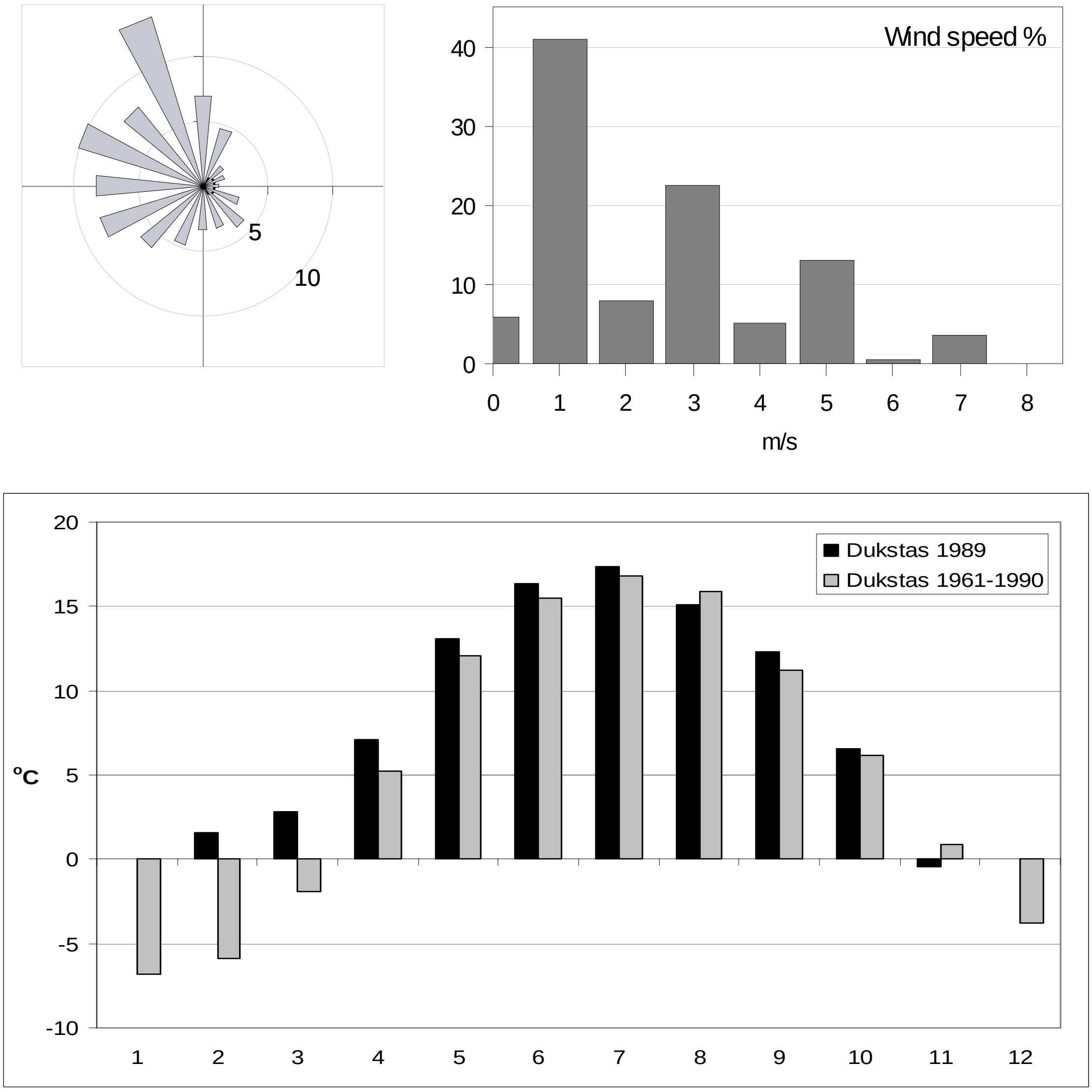
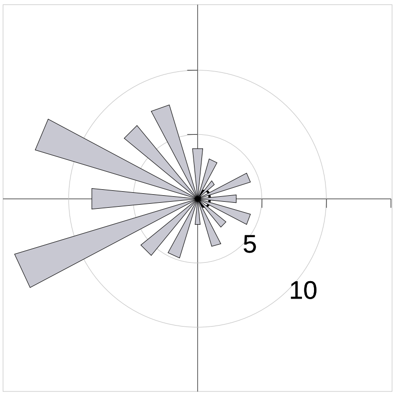
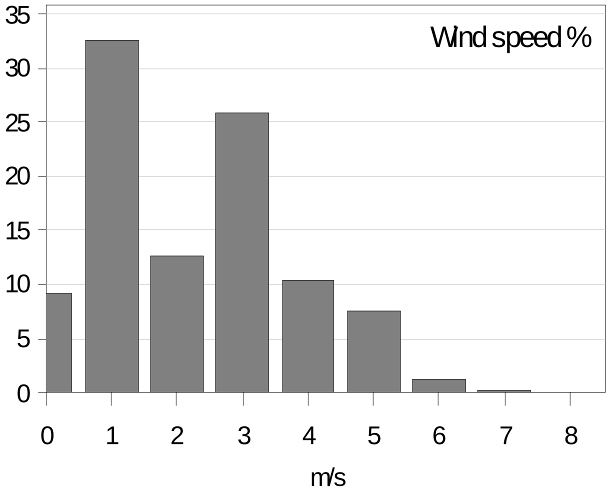


Figure 7.1-45. Wind direction and speed distributions (%) on 1.5-1.9.1989, and monthly average temperature in year 1989 at Dukstas weather station.

The year 1991 had colder May and June, but July and August were warmer when compared to average temperatures. Wind direction distribution was typical with westerly winds dominating. The average data is shown in Figure 7.1-46. Again, wind speed distribution looks somewhat strange.





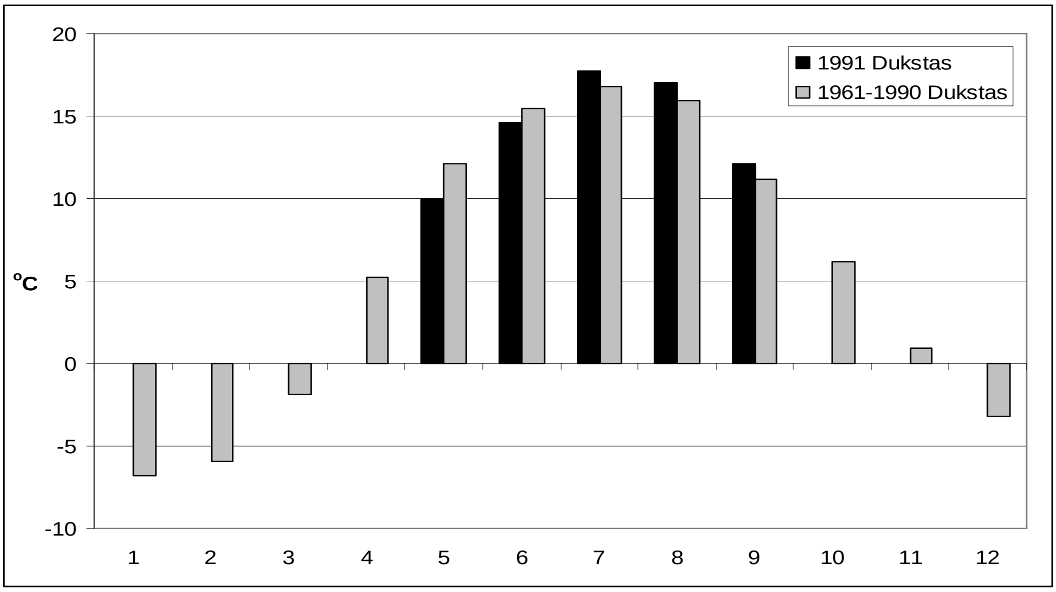
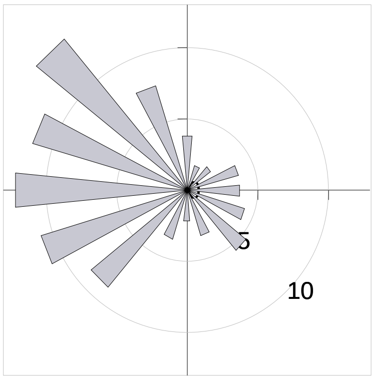
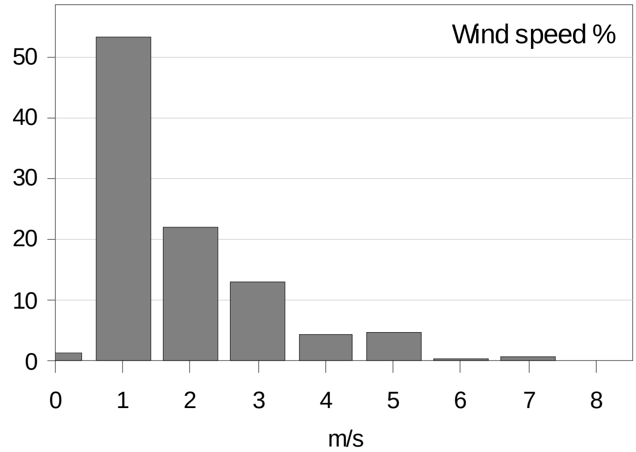


Figure 7.1-46. Wind direction and speed distributions (%) on 1.5-1.9.1991, and monthly average temperature station in year 1991 at Dukstas weather station.

The year 2002 had exceptionally high monthly average air temperatures. All summer months were warmer than average, and especially in July the monthly average temperature was four degrees warmer than the average during the period 1961-1990. Also the winds were untypical with large proportion winds from north-east and south-east. The average data is shown in Figure 7.1-47.





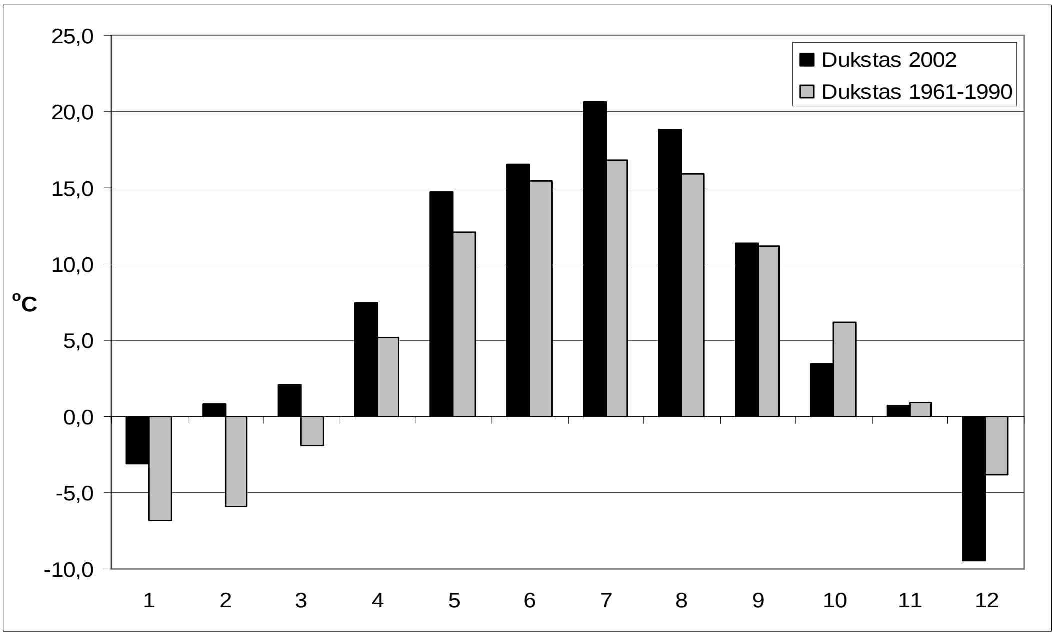


Figure 7.1-47. Wind direction and speed distributions (%) on 1.5-1.9.2002, and monthly average temperature in year 2002 at Dukstas weather station.

As a summary, the Table 7.1–38 below shows the monthly average temperatures from the calibration and simulations years.

Table 7.1–38. Monthly average temperatures (°C).

Station	Month					Average
	5	6	7	8	9	5-9
Dukstas 1981	13.9	15.7	17.6	15.2	11.5	14.8
Dukstas 1989	13.1	16.4	17.4	15.1	12.3	14.8
Dukstas 1991	10.0	14.6	17.7	17.0	12.1	14.3
Dukstas 2002	14.7	16.5	20.6	18.8	11.3	16.4
Dukstas 1961-1990	12.1	15.5	16.8	15.9	11.2	14.3

The Ignalina NPP operation data was obtained from the INPP from written records. Cooling water flow data was available as a daily total, from which daily averages were computed. The temperature rise data was computed from thermal power or electric power and efficiency figures. Figure 7.1-48 shows the flow and temperature rise figures from the calibration years 1989 and 1991. The average thermal power for the 1.5.1989-30.9.1989 period was 4483 MW, corresponding average electric power 1411 MW, and average thermal discharge to lake 3072 MW. The cooling water flow average was 83.7 m^3/s. For the period 1.5.1991-30.9.1991 the average thermal power was 5250 MW, electric power 1663 MW, thermal discharge to lake 3587 MW, and cooling water flow 91.8 m^3/s.

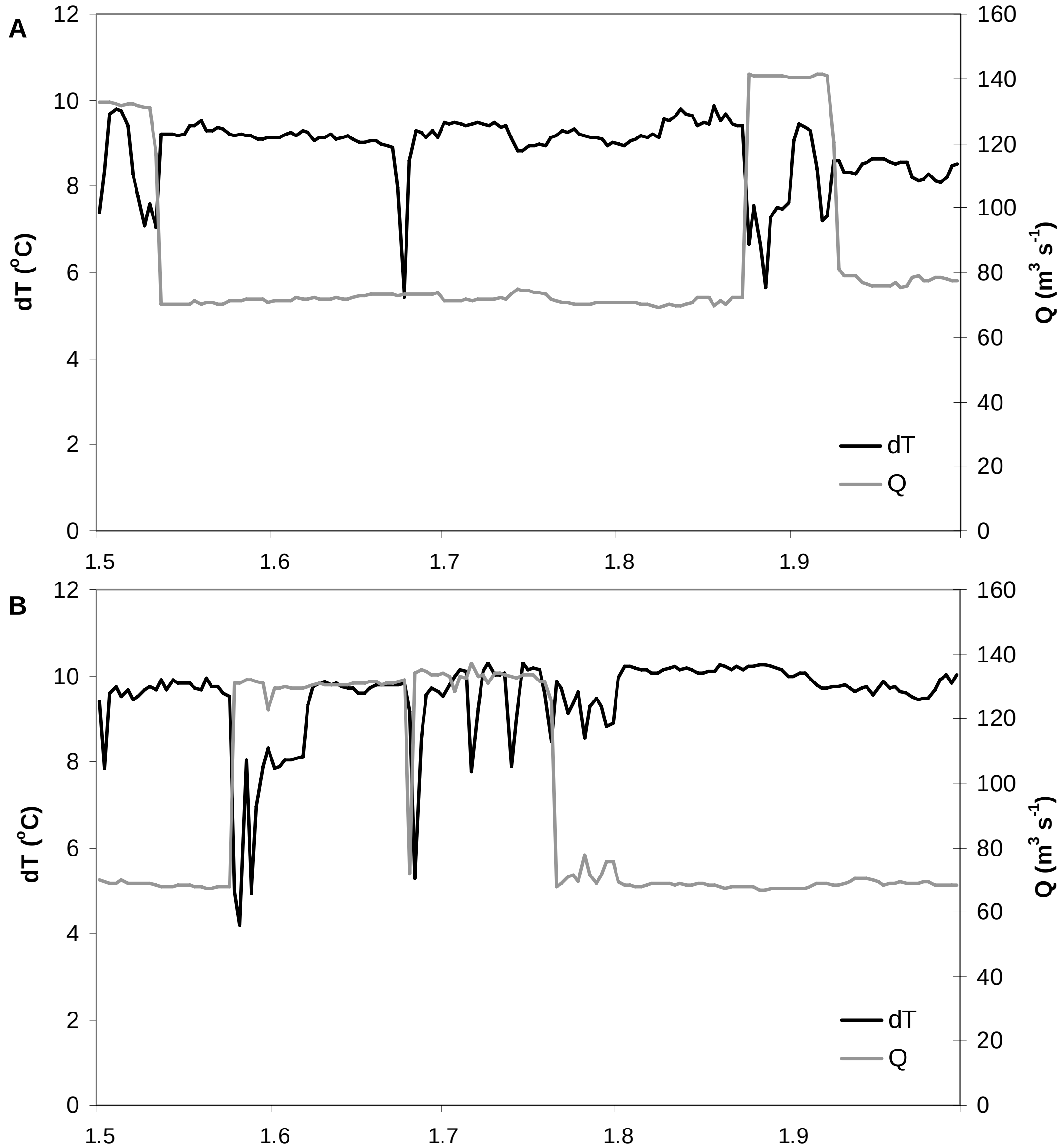


Figure 7.1-48. Operational data of the INPP in 1989 (A) and 1991 (B). Discharge of cooling water (Q) to Lake Druksiai and temperature change (dT) in the cooling process.

Flow model calibration

The flow model was calibrated against temperature measurements from years 1981, 1989 and 1991. The model simulated lake surface temperatures quite well. The average difference of computed and measured lake temperatures were less than ±1.2 degrees in all measurement points, except point P38 near the INPP outlet. In year 1981 (with no NPP) the model slightly overestimated the lake surface temperatures (by 0.2 degrees). In years 1989 and 1991, with two different INPP operation capacities, the model computed the surface temperatures almost correctly for year 1989 (± 0.6 degrees in all points), and underestimated the surface temperatures for year 1991 on the average by about 1 degree (-2 to -0.5 degrees). A summary of the average difference of computed and measured surface temperatures is shown in Figure 7.1-49.

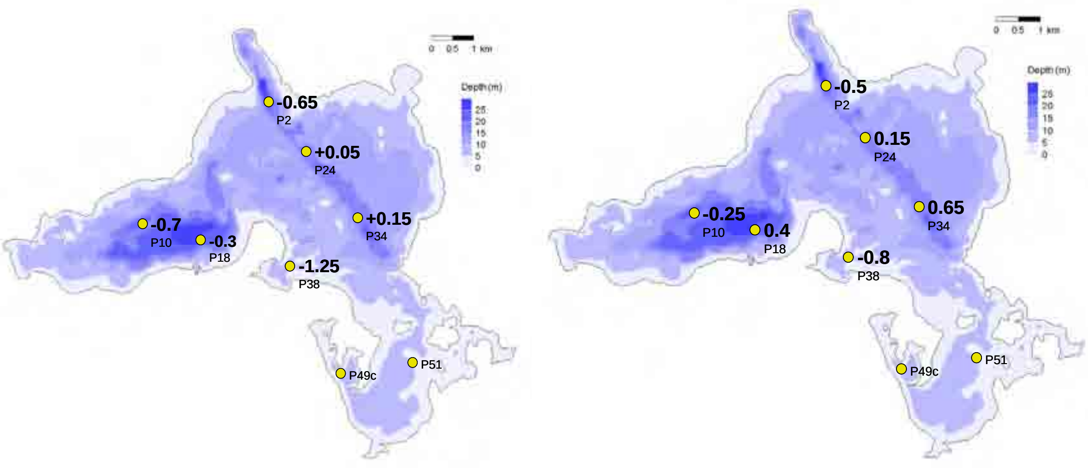


Figure 7.1-49. Average difference of computed and measured (*model result minus measurement*) values at measurement points for years 1989 and 1991 (ºC), for the whole simulation period (*left*), and for warm periods (*right*).

The flow model results from years 2001–2003 were further verified by setting the INPP outlet temperature and flow to measured values and comparing to the computed values.

The model was computed for the time period of 1.5-30.9. The measured inlet temperature and computed INPP inlet temperature are compared in Figure 7.1-50. In this figure the computed inlet values are taken from the 4-5 m depth layer in between the INPP inlets (that are in reality located 200 m apart). This value is compared to the average of the two measured inlet temperature values from the INPP. If only one of the inlets is in use then the temperature is from that inlet.

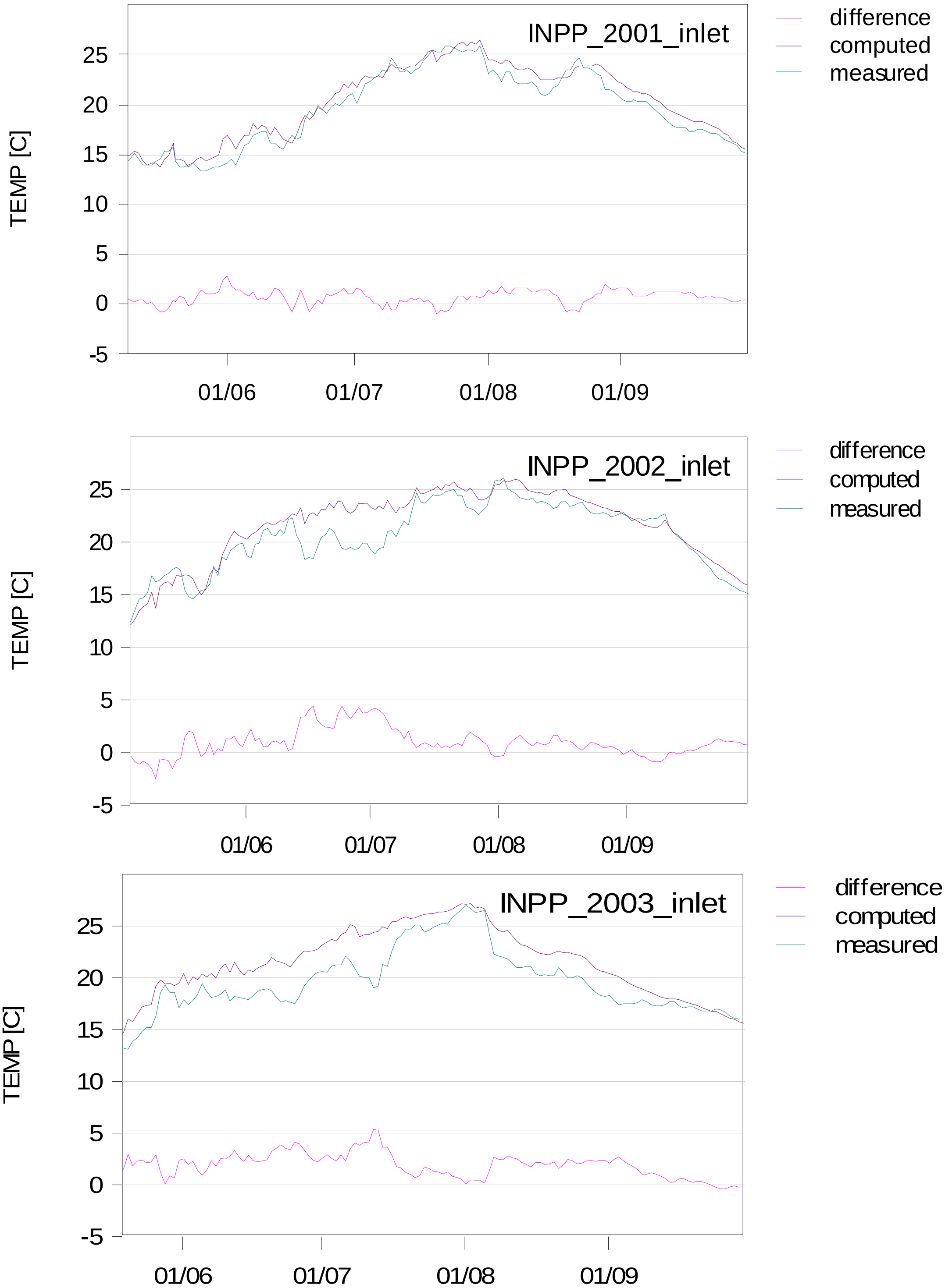


Figure 7.1-50. Computed and measured INPP inlet temperatures in years 2001, 2002 and 2003.

For year 2001 the computed inlet temperature is higher than the measured temperature. The average difference is 0.7 degrees. During the warmest period from 15.7 to 15.8 the average difference is 0.8 degrees, the computed value being higher than the measured value.

For year 2002 the computed inlet temperature is higher than the measured temperature. The average difference is 1.1 degrees, while in the end of June the difference is almost 5 degrees for a few weeks period. During the warmest period from 15.7 to 15.8 the average difference is 1.0 degree, the computed value being higher than the measured value.

For year 2003 the computed inlet temperature is, as in year 2002, higher than the measured temperature. The average difference is 1.9 degrees. In June the difference is somewhat higher than in July and August. During the warmest period from 15.7 to 15.8 the average difference is 1.4 degrees, the computed value being higher than the measured value.

The inlet location temperature correlates well with temperature in points P10, P2 and P51 (correlation coefficient > 0.95), bit worse with point P24 (cc = 0.95) and not so well with temperatures in point P34 (cc < 0.92) which is located in the middle of the lake near the INPP outlet. Near the outlet the changes in the INPP power production weaken the correlation. Therefore, the inlet temperature quite well reflects the temperature of the whole lake, and the temperature difference between measured and computed values in the inlet can be generalized to most of the lake.

The present criterion for lake temperature states that at maximum 20 % of the lake surface layer is allowed to warm to over 28 degrees. The model verifications show a slight tendency of overestimation in the model results and based on the results the area exceeding 29 to 30 degrees (depending on the year) may reflect better the actual size of the areas exceeding the present limit.

Ice cover model calibration

The ice cover computation was calibrated to Digital Globe satellite pictures obtained from Google Earth. There were three pictures available, from 9.12.2002, 14.12.2002 and 6.1.2003. The computed ice cover and corresponding digitized satellite data are shown in Figure 7.1-51.

The winter 2002-2003 used for calibration was cold and started early. The icing started already in November in the shallow southern parts of the lake, and in the end of December most of the lake was covered with ice, except in the front of the INPP outlet.

At the start of the computation period the lake temperature was set to 9 degrees in all depths. This initial temperature was estimated from the measured INPP inlet temperature. The average INPP electric power level in November was 2020 MW and cooling water flow average was 92 m^3/s, in December and beginning of January the electric power level was 2 480 MW with an average cooling water flow of 117 m^3/s. On 6.1.2003 the INPP electric power level was 2 650 MW.

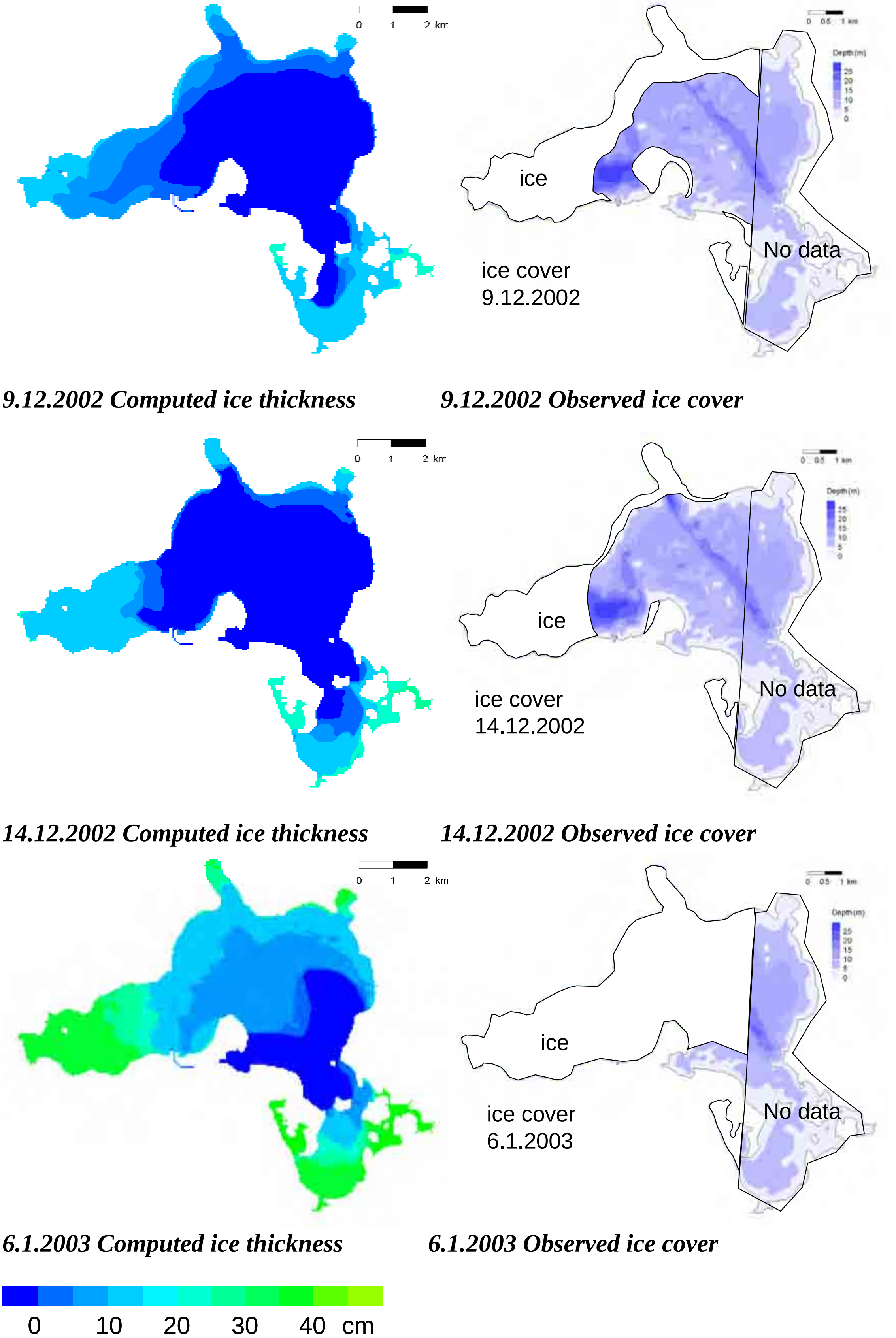


Figure 7.1-51. Computed ice thickness and observed ice cover on 9.12.2002, 14.12.2002 and 6.1.2003.

7.1.2.6.3 Thermal load dispersion computations

The effect of different levels of thermal load and different NNPP cooling water inlet and outlet locations on Lake Druksiai temperatures was investigated using the calibrated model. Additional simulations were performed to see how change of the environmental conditions would affect the computation results.

The thermal load dispersion computations were done using summer 2002 period weather data measured at the Dukstas station, with the planned NPP working at a steady power throughout the simulation. The time period used in the computations was from 1.5.2002 to 1.10.2002. The initial state of the lake was set to a constant temperature of 11 degrees in 1-4 meter layers, and 10 degrees in deeper layers. Steadying of the initial situation took about one month in the beginning of the simulation.

The year 2002 was selected for simulations, since it had the highest monthly average temperatures during the three summer months of June, July and August. Years 2001 and 2003 were also simulated using reduced set of NNPP alternatives, to investigate how the weather in different years affected the lake temperatures.

The NNPP alternatives and corresponding cooling water flows and temperature rises used in the computations are shown in Table 7.1–31. The cooling water flow and temperature rise were estimated using NNPP total efficiency of 35 %, with temperature rise between 9.5 and 10°C.

The different inlet and outlet locations used in the computations are shown in Figure 7.1-52. There are three alternative inlet locations: the present location, a location about 2 km west from the present location, and a tunnel from the deeper part of the lake. The two outlet locations are the present location in the middle of the lake, and a southern outlet to the end of a bay guiding the cooling water to the southern part of the lake.

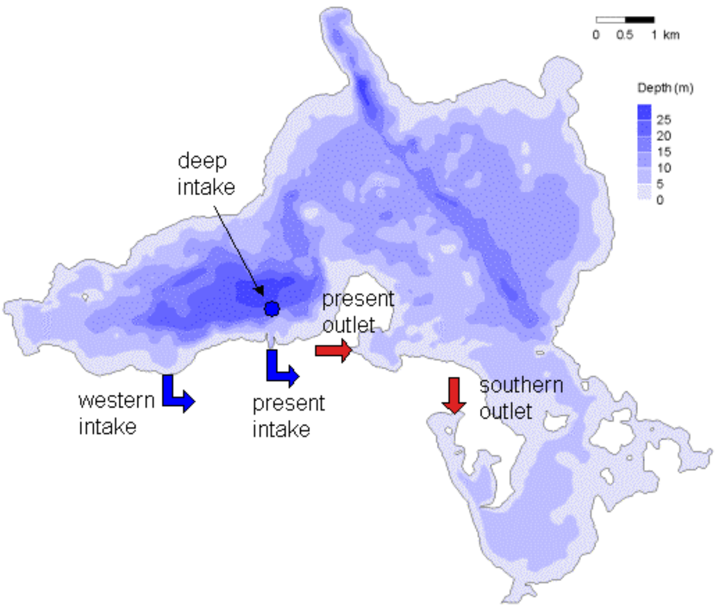


Figure 7.1-52. Alternatives of the NNPP intake and outlet locations used in the computations.

Thermal load levels

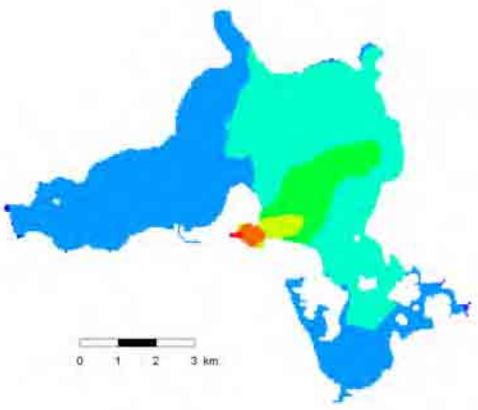
To investigate the effect of thermal load from NNPP to the lake temperature, six alternative levels of thermal load to the lake ($MW_{released}$) were simulated, using present cooling water intake and outlet locations. The corresponding amount of electrical energy produced assuming direct cooling and plant efficiency of 35 % is presented in brackets (MW_e). The following levels were computed:

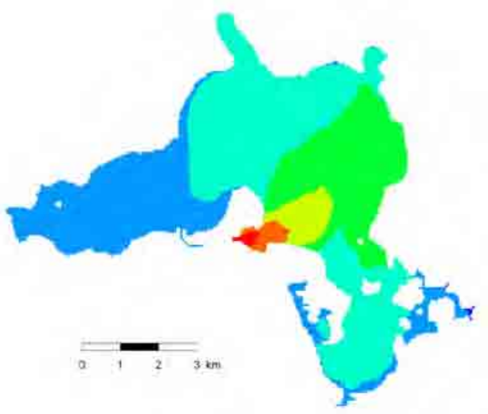
- 1 390 $MW_{released}$ (750 MW_e)
- 2 230 $MW_{released}$ (1 200 MW_e)
- 3 160 $MW_{released}$ (1 700 MW_e)
- 4 460 $MW_{released}$ (2 400 MW_e)
- 5 200 $MW_{released}$ (2 800 MW_e)
- 6 310 $MW_{released}$ (3 400 MW_e)

As a result the simulation produced time-dependent 3-dimensional temperature fields for the whole lake. These results are summarized below using two types of visualisations:

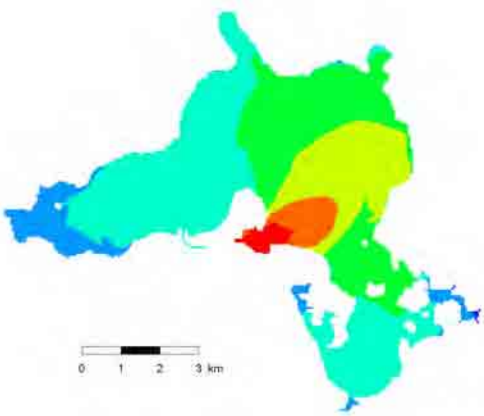
- surface temperature fields averaged over July;
- percentage of the lake area exceeding the threshold temperatures of 28 and 30 degrees as a function of time.

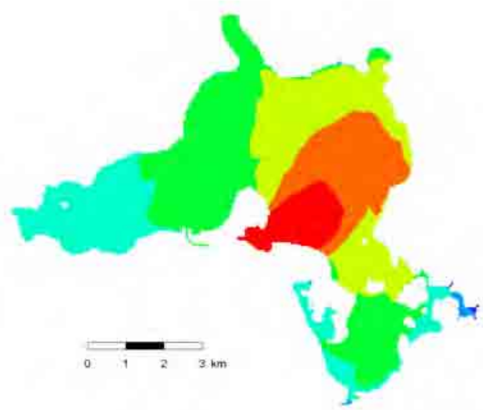
Figure 7.1-53 shows the average temperature distribution during July 2002 for four thermal load alternatives. The shape of temperature distribution remains similar between different thermal load alternatives, but the temperature level rises when thermal load is raised.





2 230 $MW_{released}$ ***3 160 $MW_{released}$***

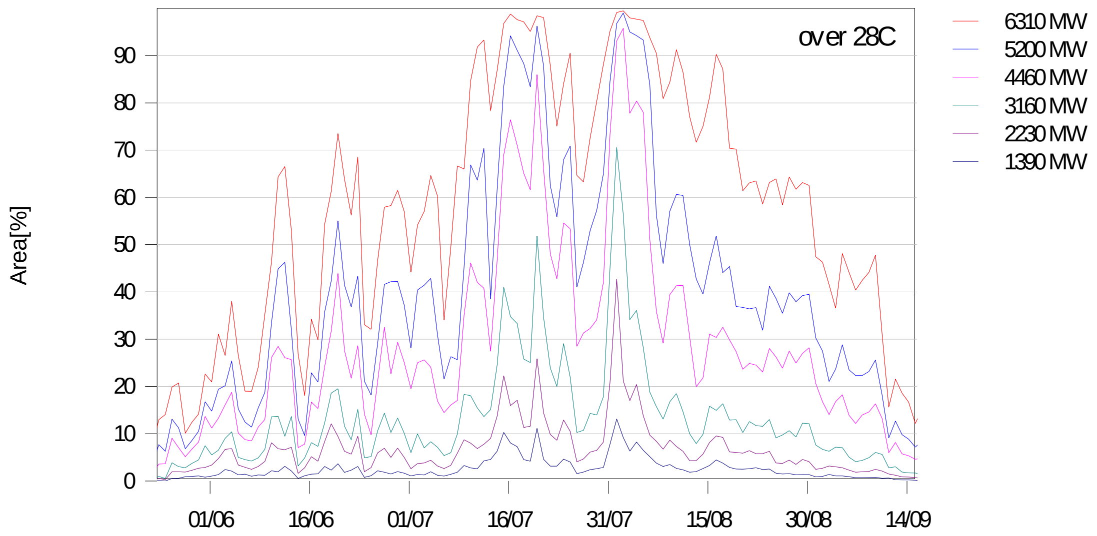




4 460 $MW_{released}$ ***6 310 $MW_{released}$***

Figure 7.1-53. Average temperature fields (°C) of the lake influenced by different thermal loads in July 2002.

Figure 7.1-54 shows the area of the lake that exceeds a given temperature for the whole simulation period as a percentage of the lake area. For thermal loads of 1 390 $MW_{released}$ and 2 230 $MW_{released}$ the lake area warmed over 28 degrees remains below or near the 20 % limit. For load of 3 160 $MW_{released}$ the limit is exceeded in the second half of June and in the beginning of August 2002. For loads 4 460 $MW_{released}$ or more, over half of the lake warms to over 28 degrees during the warmest summer period.



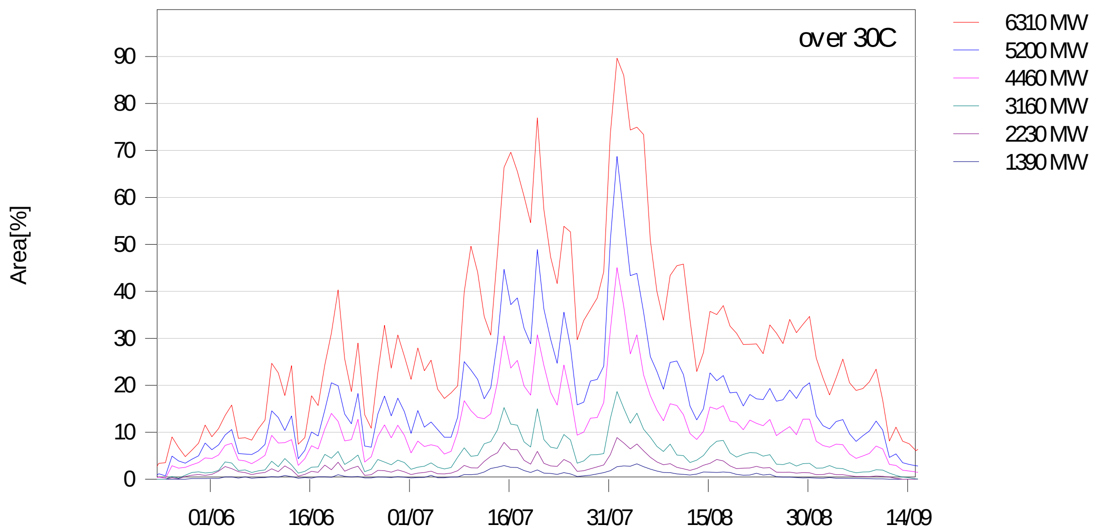


Figure 7.1-54. Proportion of the lake surface area (daily average) heated to over 28 °C (a) and to over 30 °C (b) by thermal load from 1 390 to 6 310 $MW_{released}$.

The computed summertime average lake surface temperature in the middle of the lake depends linearly on the thermal load. Figure 7.1-55 shows the computed average temperatures in point P24 as a function of the thermal load. The temperature rises about 2°C for each 2 000 MW of thermal load released to the lake. The above number is computed for year 2002 and for point P24, in other years and in different points the temperature rise may be different, as can be seen from the similar data computed for the point P38 for the same year.

The number of days when the temperature exceeds a given limit is shown as a function of the NNPP thermal load in Figure 7.1-56. For a limit of 28 degrees, the number of days starts to rise steeply after thermal load of 2 000 – 3 000 $MW_{released}$. For a limit of 30 degrees, the steep rise starts at thermal load level of 3 500 – 4 500 $MW_{released}$. The values depend strongly on weather data of simulation year, and these figures are valid for year 2002 only. It should be noted that even though the absolute temperature values do depend strongly on the weather conditions, the relative difference between modelled scenarios does not depend strongly on the weather.

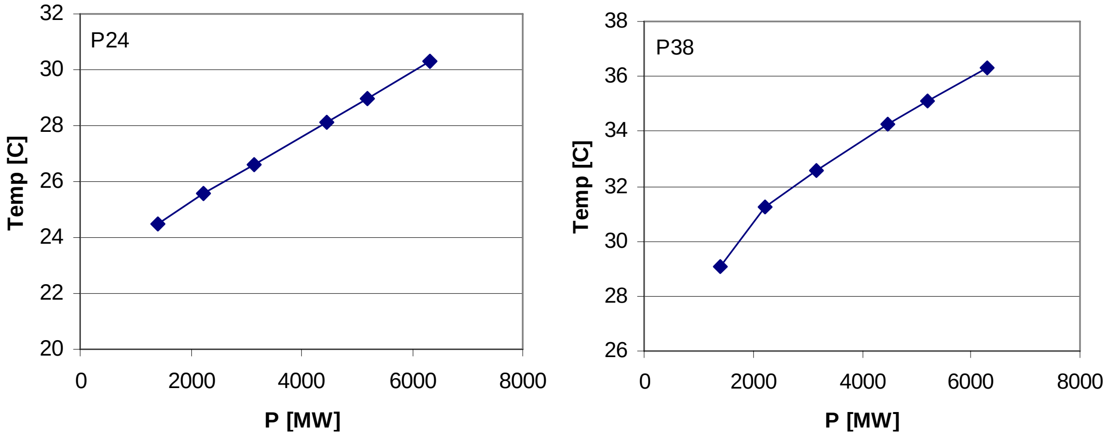


Figure 7.1-55. Dependency of average water temperature at points P24 and P38 on the NNPP thermal load in model simulations. Regression line for P24 is T = 0.00217 P + 22.88, goodness of fit is 0.99. Selected simulation period was 1.6-1.9.2002.

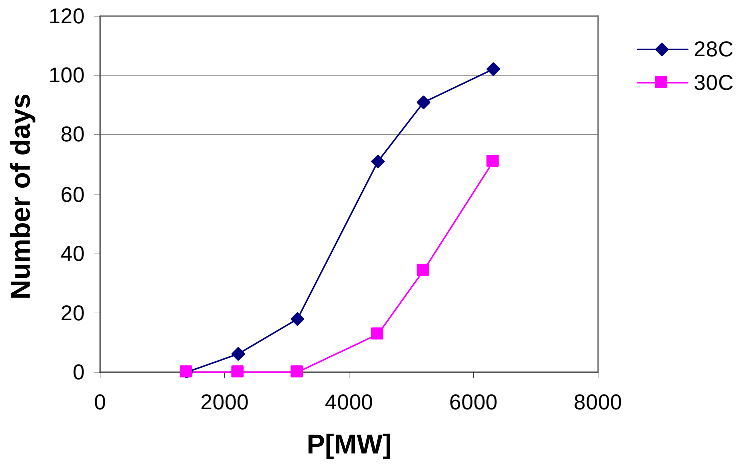


Figure 7.1-56. Dependency of the number of days when 20 % of the lake surface area warms over given temperature limit on the NNPP thermal load, simulation year 2002.

The lake surface temperature rise caused by the NNPP can be approximated by subtracting a reference temperature field computed without the NNPP from a scenario temperature field computed with the operating NNPP. Figure 7.1-57 shows temperature rise fields computed from the average temperature fields for July 2002 for the thermal loads 2 230, 3 160, 4 460 and 5 200 $MW_{released}$. The average lake surface temperature in July 2002 without the NPP was 23.5°C, with minimum values of 22.9 and maximum of 24.5 °C. Figure 7.1-58 shows the size of areas that warmed over a given temperature for different thermal loads.

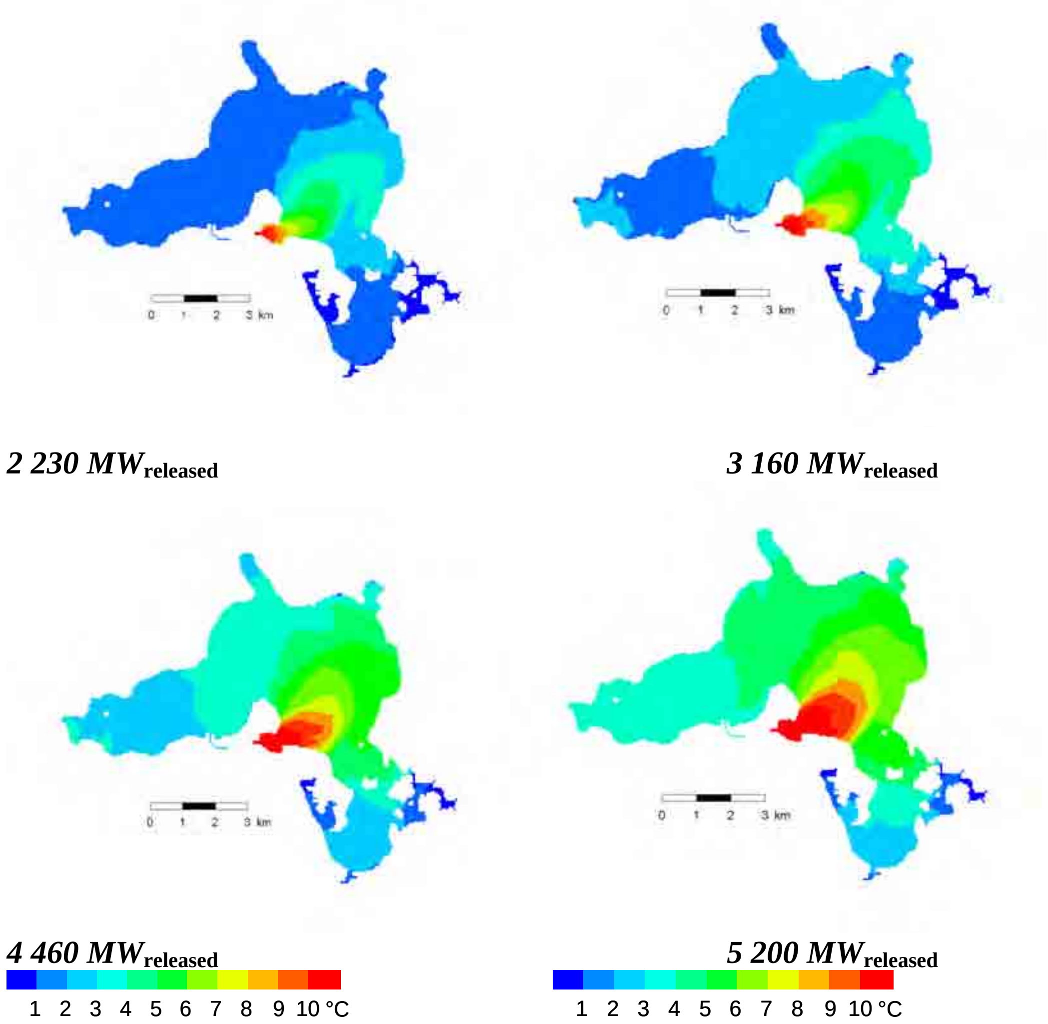


Figure 7.1-57. Average lake surface temperature rise in July 2002 for thermal loads 2 230, 3 160, 4 460 and 5 200 $MW_{released}$.

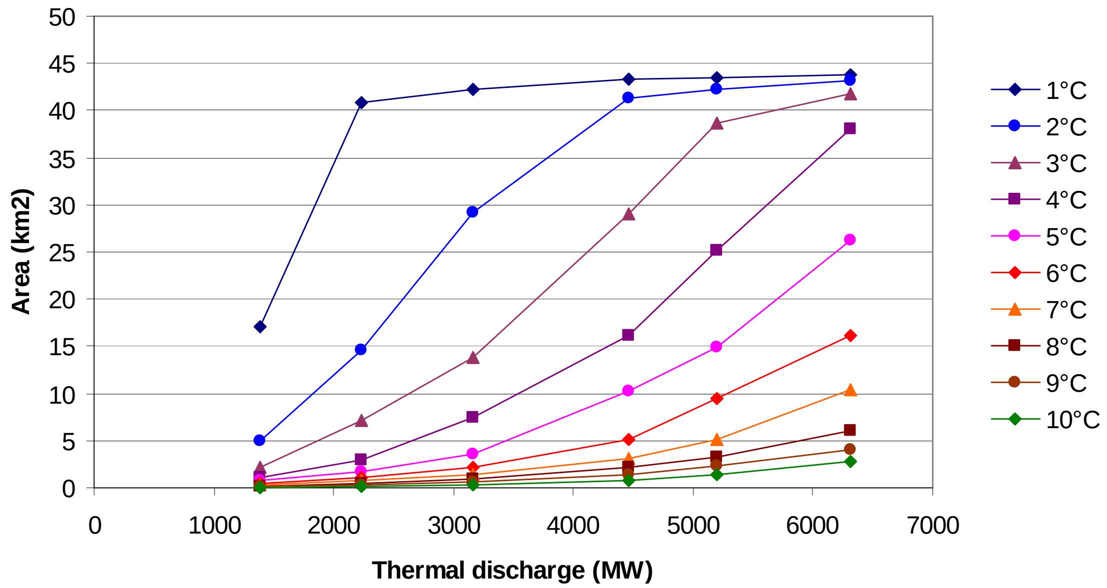
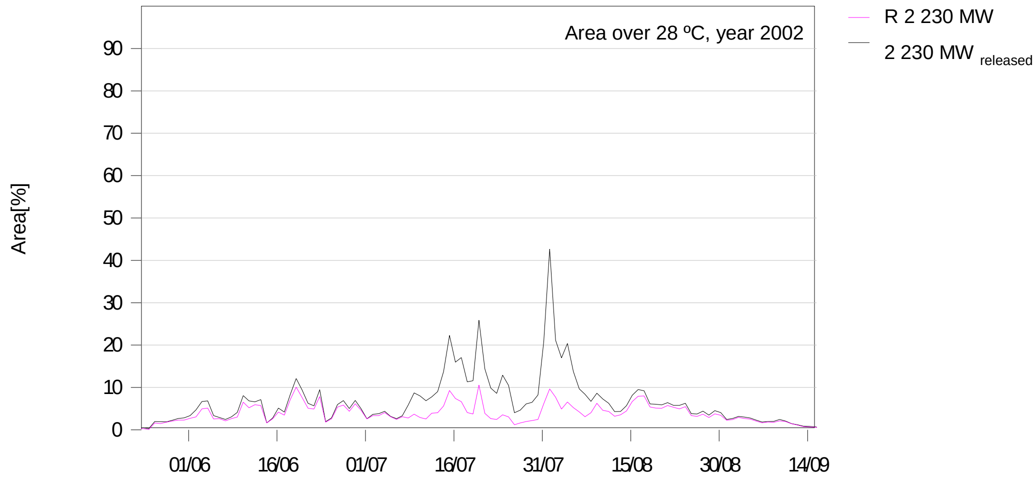


Figure 7.1-58. Area of lake surface temperature rise as a function of the thermal load, average of July 2002 for temperature rises of 1-10 °C.

Thermal load reduction during summer

To investigate the effect of reducing the thermal load from NNPP to the lake during the warmest, ecologically most critical, time period two thermal load reduction scenarios were created. The reduction scenarios were computed using 50 % of the NNPP power level for the period of 10.7-10.8.2002. Scenarios were computed for NNPP thermal load levels 2 230 $MW_{released}$ and 3 160 $MW_{released}$, and compared to results without reduction.

Figure 7.1-59 shows proportion of the lake surface area heated to over 28 ^{o}C as a daily average by thermal load levels 2 230 $MW_{released}$ and 3 160 $MW_{released}$ compared to scenarios without power reduction. The results show that thermal load reduction has a clear effect on the size of the area warmed up, reducing it during the warmest summer period below 20 % of the lake area. For the 2 230 $MW_{released}$ the 20 % limit is not exceeded, and for the 3 160 $MW_{released}$ thermal load the 20 % limit is exceed on two days.



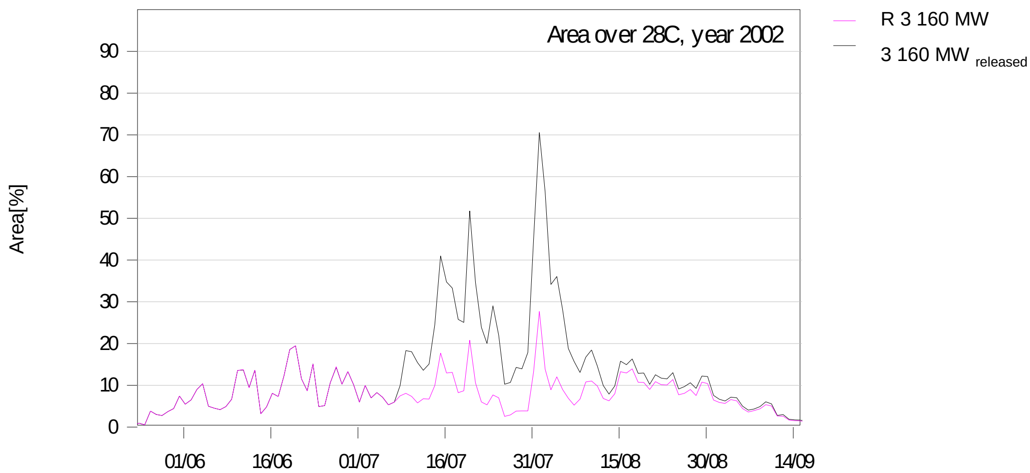


Figure 7.1-59. Proportion of the lake surface area (daily average) heated to over 28 ^{o}C by thermal load from 2 230 and 3 160 $MW_{released}$. The pink line (R) indicates the thermal load reduction scenario, black line the "normal" scenario without reduction.

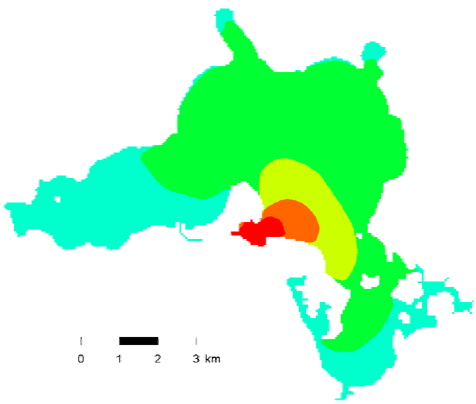
Inlet and outlet alternatives

To investigate the effect of NNPP inlet and outlet locations on lake temperatures, six alternative NNPP inlet and outlet location combinations were computed. The following inlet and outlet combinations were used:

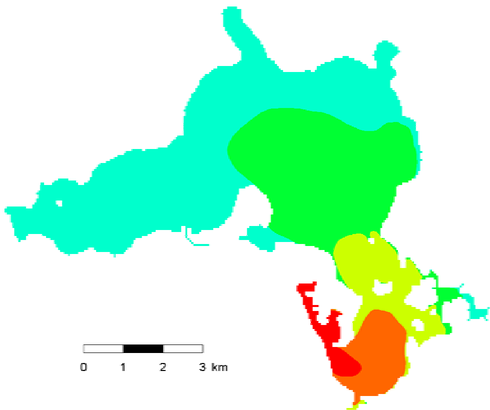
PP	–	**p**resent inlet and **p**resent outlet
DP	–	**d**eep inlet and **p**resent outlet
PS	–	**p**resent inlet and **s**outhern outlet
WP	–	**w**estern inlet and **p**resent outlet
WS	–	**w**estern inlet and **s**outhern outlet
PD	–	**p**resent inlet and **d**ivided outlet

Figure 7.1-60 shows the average temperature distribution during July 2002 for scenarios PP, PS, WP and WS with 3 160 $MW_{released}$ thermal load.

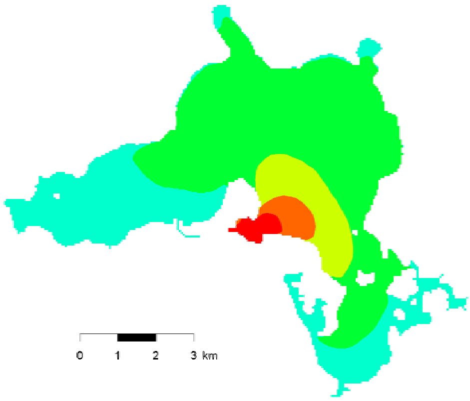
Relocating the inlet to the western location has only a small effect on the surface temperature distribution near the inlet location. The western inlet reduces the warmed up areas a little, as the NNPP inlet water is slightly cooler than in the present inlet option.



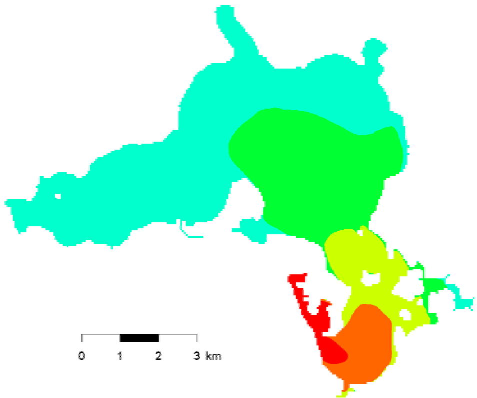
PP *– present inlet, present outlet*



PS *– present inlet, southern outlet*



WP *– western inlet, present outlet*

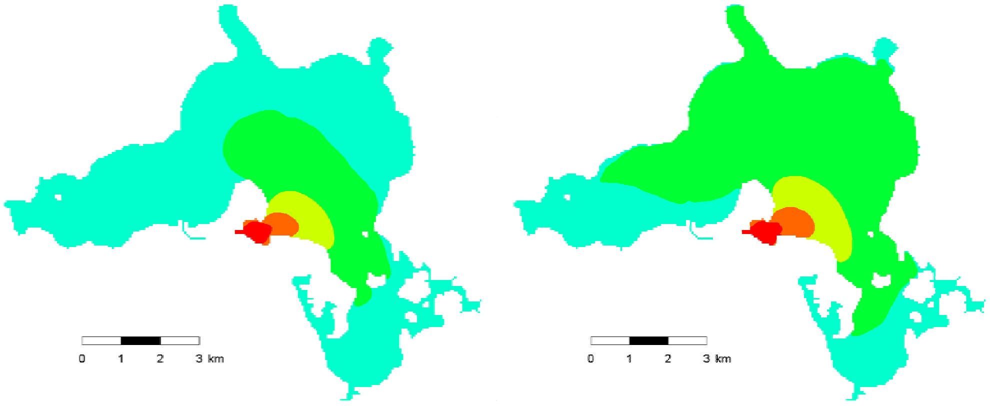


WS *– western inlet, southern outlet*

Figure 7.1-60. Average temperature field of the lake with thermal load of 3 160 $MW_{released}$ in July 2002 in different inlet – outlet alternatives.

Relocating the outlet to the southern alternative completely changes the temperature distribution: the western part of the lake remains cooler, while the southern part of the lake and especially the bay to which the outlet discharges, warms up significantly. When using the southern outlet the temperature in the middle of the lake decreases about 1 degree, and at the inlet the decrease is about 0.4 degrees. The southern part of the lake warms up about 4 degrees.

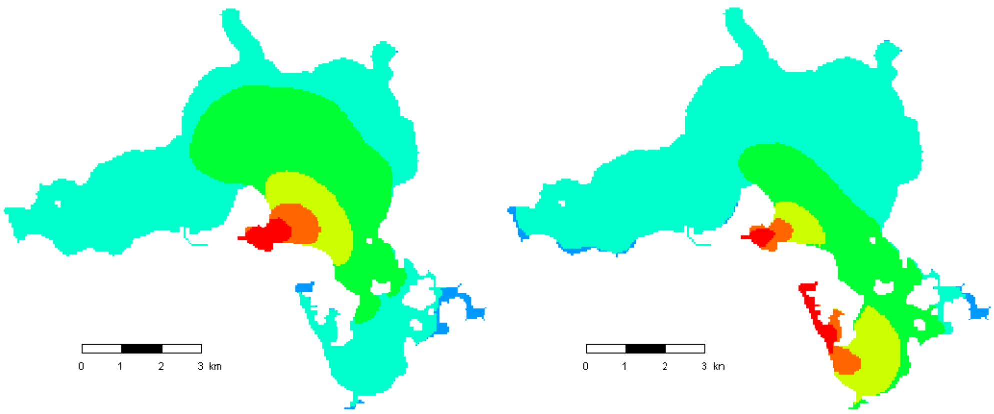
Temperature fields of the PP and DP options are shown in Figure 7.1-61. The deep inlet option for 2 230 $MW_{released}$ thermal load warms the lake more than the present inlet option. In the model run the cold water storage of the deeper layer lasts about 1.5 months, after which the inlet temperatures closely resemble the surface inlet temperatures. After this initial period the thermocline no longer exists near the inlet, and the mixing of the warmer surface water to deeper layers becomes more intense. This reduces the lake surface temperature and thus reduces also cooling of the lake to the atmosphere. During hot summer months the lake is already warmed up and therefore also the surface warms to higher temperatures than with the present inlet.



***PP** — present inlet, present outlet*   ***DP** — deep inlet, present outlet*

Figure 7.1-61. Average temperature field of the lake with NNPP thermal load of 2 230 $MW_{released}$ in July 2002 in deep and present inlet alternatives.

Dividing the 4 460 $MW_{released}$ cooling water outlet to two locations reduces temperatures in the middle part of the lake. At the same time the bay to which the southern outlet flows, and also the southern part of the lake warms up. This option reduces the area warmed over 28 degrees, and also the temperatures in the eastern part of the lake. The PP and PD scenario temperature fields are shown in Figure 7.1-62. In the divided outlet option the temperatures in the middle of the lake and also at the NNPP inlet are somewhat colder than in the present outlet option.



PP — *present inlet, present outlet* ***PD*** — *present inlet, divided outlet*

Figure 7.1-62. Average temperature field of the lake with NNPP thermal load of 4 460 $MW_{released}$ in July 2002, in present and divided outlet scenarios.

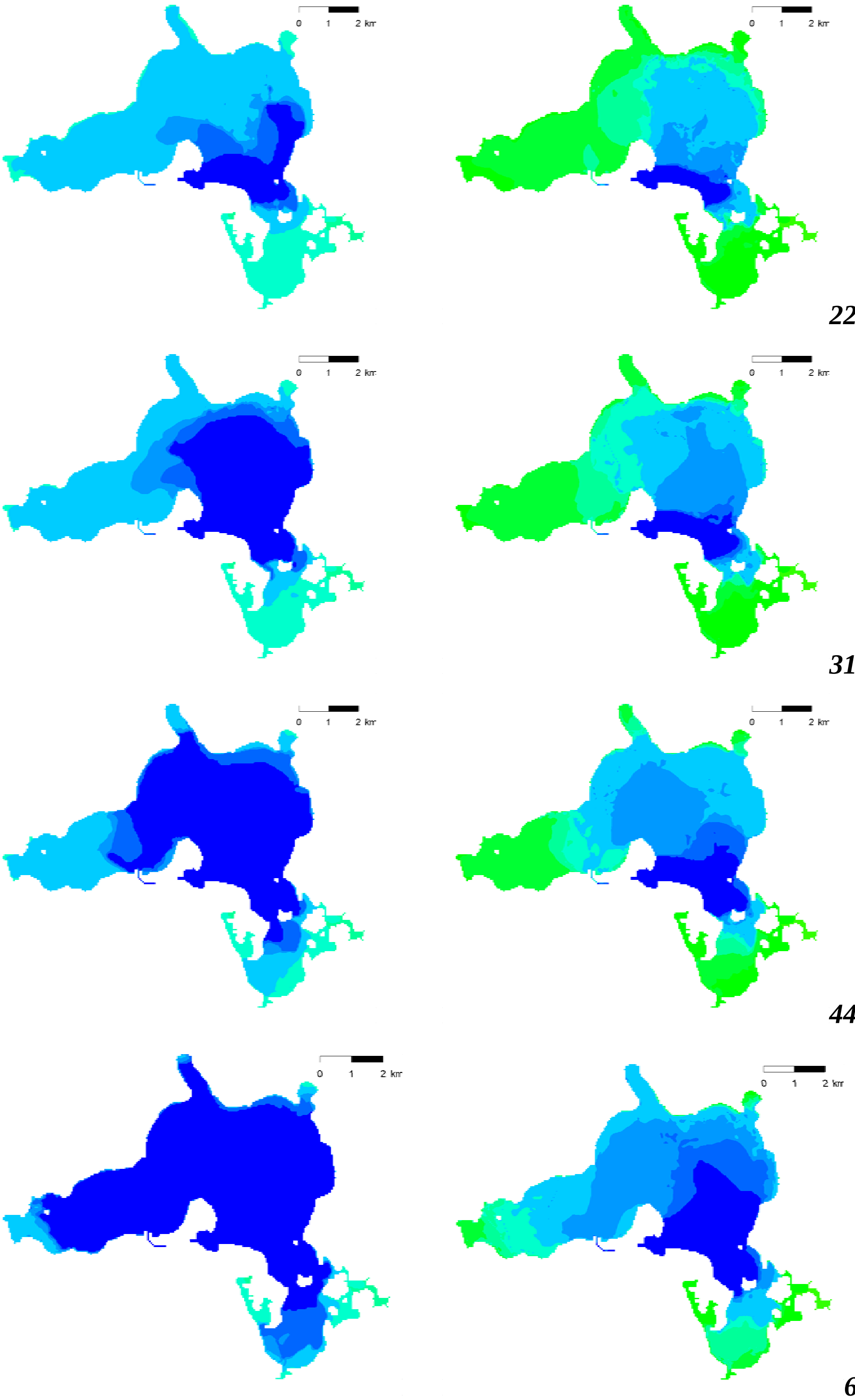
Impacts on ice cover

Wintertime ice conditions were simulated using four different NNPP thermal load levels, 2 230, 3 160, 4 460 and 6 310 $MW_{released}$. The simulation period was from 1.11.2002 to 6.1.2003.

The temperatures in January 2003 were low, thus these values represent the minimum open water area size (Figure 7.1-63). With a thermal load of 2 230 $MW_{released}$ a water area of 2.4 km^2 stayed free of ice. The ice free area increased to 5 km^2 with 4 460 $MW_{released}$ and respectively to 9 km^2 with 6 310 $MW_{released}$.

On the simulations from December 2002 the effects of different thermal loads on the areas frozen can be seen clearly. With the 2 230 $MW_{released}$ thermal load the ice free area is located close to the NNPP outlet. Thermal loads of 4 460–6 310 $MW_{released}$ keep the main part of the lake open longer from the start of the winter. In general the effect on the ice cover in the southern and western part of the lake is smaller compared to the central parts of the lake.

14.12.2002	*6.1.2003*



2230 MW

3160 MW

4460 MW

6310 MW

0 10 20 30 40 cm   0 10 20 30 40 cm

Figure 7.1-63. Computed ice cover on 14.12.2002 (*left*) and 6.1.2003 (*right*) using NNPP thermal loads of 2 230, 3 160, 4 460 and 6 310 $MW_{released}$.