

6 WASTE

6.1 CONSTRUCTION OF THE NUCLEAR POWER PLANT

The estimated construction time of a new NPP is 4–7 years, and no radioactive waste will be generated during this stage. In spite of this, a relevant amount of conventional waste will be produced and will have to be disposed of appropriately.

There are different construction stages: earthworks, construction of unit(s), installation works, commissioning etc. The waste produced typically will be civil industry waste resulting from erection of reinforced concrete structures, installing of equipment and organizing of construction activities (i.e. construction debris, packaging material waste, personnel sanitary waste, waste water polluted with petroleum products and so on).

The first step in the construction of the NNPP will be the earthworks. The depth of the NNPP construction site will vary from 8 to 16 meters. The removed soil will be moved to the projected soil dump located next to the site. The soil dump area is about 240 000 m² large and is capable of accommodating 700 000 m³ of soil (see Section 7.4).

Excavated soil amounts will be in the order of 850 000 m³ for one NPP unit, and 1 400 000 m³ for two units. Some of the removed soil will be moved back to the NNPP construction site and the rest will be left for final storage at the soil dump.

During the construction phase, a significant amount of solid ordinary waste will be generated, generally comprising construction and domestic waste. Types of waste that will be commonly encountered together with an indicative estimation of the total amount can be found in Table 6.1-1.

Table 6.1-1 Amounts of ordinary waste generated during the construction of the new NPP.

Type of waste	1 × 1600/1700 MW reactor	2 × 1600/1700 MW reactors
Paper	Total amount: 14 500 t 1 000–2 000 t not suitable for further utilization (lower limit) 385 t/month as peak quantity	Total amount: 27 000 t 2 000–4 000 t not suitable for further utilization (lower limit) 740 t/month as peak quantity
Glass		
Packaging waste		
Metal scraps		
Electronic scraps		
Tyre scraps		
End-of-life vehicles		
Sewage sludge		
Concrete sludge		
Lead batteries		
Contaminated soils		
Used oils		
Residual paints, solvents		
Drinking and raw water – waste water treatment	730 000 m ³ 20 000 m ³ /month as peak quantity	1 400 000 m ³ 40 000 m ³ /month as peak quantity

The exact amounts, nature and volumes are linked to variables that can only be clarified as the project proceeds, such as reactor type and number, final layout of the site etc.

Considering a construction period of 50–55 months, the peak in solid waste production will rapidly be reached around the very end of the first year and during the second year of construction, slowly and steadily decreasing afterwards. The rough estimations of the peak amounts can be found as well in Table 6.1-1.

The waste types can be divided into different categories:

- Recyclable materials: to be segregated and stockpiled separately;
- Bio-waste: collected in separate drums, cans or bins;
- Electrical goods and electronic scraps;
- Energy waste (waste potentially available for waste to energy plant, like paper and paperboard);
- Timber waste;
- Waste placed on landfill;
- Hazardous waste.

The proportions of these different categories, as well as the amounts that will be recycled or incinerated will depend on the organization of the licensed waste management company, and on the site specific operations. With a responsible waste management, including waste recycling enhancement and the availability of waste to energy technologies, the amount of waste ending on landfills could be limited to the amounts estimated in Table 6.1-1.

The quality of both the terrestrial environment and the lake's water can potentially be contaminated by inappropriate handling and disposal of waste during construction and operation of the new NPP.

A licensed waste management company, the winner of the public tender for the waste management of the new NPP, will be given the responsibility of the waste treatment and disposal, following the Lithuanian Law on Waste Management (*State Journal, 1998, No. 61-1726; 2002, No. 72-3016*), Regulations for Waste Management (*State Journal, 2004, No. 68-2381*) and Permission on integrated prevention and control of pollution. Solid waste will be properly handled and stored until the final disposal from site to appropriate off-site licensed landfill areas. When possible all staff shall minimize the amount of waste and water generated from their daily activities, opportunities for recycling or reuse shall be investigated and implemented if practical and cost effective. The contractor is obliged to manage all waste material generated during construction and to provide any remediation work required to leave the construction and soil dump areas in a neat and clean condition.

Concerning the amounts of potable and raw water resulting in waste water that will have to be treated, some rough estimation of the total consumption is also provided in Table 6.1-1. These figures are strictly connected to the amount of workers needed for the construction of the power plant. Considering the construction of one reactor, or different reactors built in the same timeframe of 50–55 months, the monthly waste water treatment rate will reach its peak at the end of the second year of construction and at the beginning of the third, when the amount of workers is the largest. Beforehand and afterwards, the amount will grow/diminish constantly.

Flammable/combustible waste, oxidizing waste, corrosive waste, toxic waste, and other waste classified as hazardous will also be generated and will be handled specifically. All these amounts will be sorted, packaged and confined by the contracting company and then transported by a licensed contractor to a licensed disposal site outside the construction site. Other hazardous waste like chemicals and hydrocarbons (coolants, waste oils, solvents, and other chemicals) will also be generated during the construction

phase. All these amounts are difficult to estimate and largely depend on the construction activities and on site specific operation.

Liquid waste (including sewage, residual oils etc.) will be routed to suitable intermediate storage and / or drainage systems. In particular, direct discharge to the lake of polluted sewage waste water will be prohibited. Sewage water will be treated at a waste water treatments plant in an appropriate manner. Sewage water will be managed in accordance with the requirements of the “Regulation on Sewage Management” (*State Journal, 2007, No. 110-4522*).

A storm sewer system will also be implemented. Surface water will be managed in accordance with the requirements of the “Regulation on Surface Water Management” (*State Journal, 2007, No. 42-1594*).

Appropriate waste and waste water handling will be included in the environmental management system of the new NPP construction site.

6.2 OPERATION OF THE NUCLEAR POWER PLANT

6.2.1 Non-radioactive waste

Solid non-radioactive waste generated during operation of the NPP will be for example utility type and non-hazardous waste (paper, plastic, etc.) and hazardous waste generated during the maintenance (burnt-out fluorescent lamps, batteries, used oil, etc.). In this case the waste will be managed according to the Lithuanian Law on Waste Management (*State Journal, 1998, No. 61-1726; 2002, No. 72-3016*), the requirements of the Regulations for Waste Management (*State Journal, 2004, No. 68-2381*) and Permission on integrated prevention and control of pollution. The possible amounts of waste generated during the proposed economic activity, the ways of management, disposal and utilisation of waste are presented in Table 6.2-1.

Table 6.2-1. Waste and waste management during operation phase of the NNPP.

Technological process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Annual amount (1 reactor) tonnes	Annual amount (2 reactors) tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness ¹	Storage conditions	Maximum amount, tonnes	
Power plant operation	Municipal waste	110	205	solid	20 03 01	Non-hazardous	Temporary storage in containers	10	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Maintenance waste	15	25	solid	15 02 03	Non-hazardous	Temporary storage in containers	4	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Paper	30	60	solid	20 01 01	Non-hazardous	Temporary storage in containers	5	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Waste suitable for energy production	55	105	solid	15 01 03	Non-hazardous	Temporary storage in containers	6	Transfer to waste consumption enterprises
Power plant operation	Organic waste	30	55	solid/liquid	20 02 01	Non-hazardous	Temporary storage in containers	5	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Metal	80	150	solid	20 01 40	Non-hazardous	Temporary storage in containers	8	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Wood	120	230	solid	20 01 38	Non-hazardous	Temporary storage in containers	20	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Glass	1	1.5	solid	20 01 02	Non-hazardous	Temporary storage in containers	2	Transfer to waste consumption or disposal in specially equipped dump
Power plant operation	Electrical and electronic components	7	14	solid	20 01 35	Hazardous	Temporary storage in containers	5	Transfer to hazardous waste disposal licensed enterprises

Techno-logical process	Waste							Waste storage at site		Proposed methods of waste management
	Name	Annual amount (1 reactor) tonnes	Annual amount (2 reactors) tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness ¹	Storage conditions	Maximum amount, tonnes		
Power plant operation	Solid oily waste	15	30	Solid/liquid	15 02 02	Hazardous	Temporary storage in containers	9	Transfer to hazardous waste disposal licensed enterprises	
Power plant operation	Coolants	3	6	Liquid	16 01 14	Hazardous	Temporary storage in containers	2	Transfer to hazardous waste disposal licensed enterprises	
Power plant operation	Solvents	3	6	Solid/liquid	20 01 13	Hazardous	Temporary storage in containers	2	Transfer to hazardous waste disposal licensed enterprises	
Power plant operation	Batteries	0.5	1	Solid	20 01 33	Hazardous	Temporary storage in containers	0.2	Transfer to hazardous waste disposal licensed enterprises	
Power plant operation	Fluorescent tubes	0.3	0.6	Solid	20 01 21	Hazardous	Temporary storage in containers	0.2	Transfer to hazardous waste disposal licensed enterprises	
Power plant operation	Boric Acid (H ₃ BO ₃)	2	4	Liquid	CAS No.11113-50-1 EINECS 234-343-4	Irritant	No storage on site	-	Boric acid will be included in the effluent from the primary system. Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – 2 tonnes, maximum – 7 tonnes.	
Power plant operation	Lithium hydroxide (LiOH)	Less than 0.001	Less than 0.001	Liquid	CAS No 1310-65-2 EINECS 215-183-4	Toxic	No storage on site	-	Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – < 1 kg/unit, maximum – 4 kg/unit.	

Techno-logical process	Waste						Waste storage at site		Proposed methods of waste management
	Name	Annual amount (1 reactor) tonnes	Annual amount (2 reactors) tonnes	State of aggregation (solid, liquid, paste)	Code according to the Waste List	Hazardousness ¹	Storage conditions	Maximum amount, tonnes	
Power plant operation	Hydrazine (N ₂ H ₄)	0.007	0.014	Liquid	CAS No. 302-01-2 EINECS 206-114-9	Flammable; Carcinogenic	No storage on site	-	Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – 7 kg, maximum – 14 kg.
Power plant operation	Ammonia	0.02	0.04	Liquid	CAS No. 1336-21-6 EINECS 215-647-6	Carcinogenic	No storage on site	-	Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel. Expected annual discharge – 20 kg
Power plant operation	Sodium hydroxide 50% concentration	50	100	Liquid	CAS No. 2815 12 00 02	Carcinogenic	No storage on site		Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel.
Power plant operation	Sulphuric acid 93% concentration	28	56	Liquid	CAS No. 7664-93-9 EINECS 231-639-5	Carcinogenic	No storage on site		Process waste water will be treated in liquid radioactive waste management system. Treated waters will be discharged in the cooling water channel.

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*).

The total amount of conventional waste generated every year is around 450–500 tonnes for one reactor unit, 850–900 tonnes if 2 units will be placed in operation. The exact amounts of these different materials, as well as the shares that will be recycled, placed in landfill or incinerated, will depend on the organization of the licensed waste management company, and on the site specific operations. With a responsible waste management, including recycling waste enhancement and the availability of waste to energy technologies, the amount of waste ending on landfill could be limited down to 10 % of the total amount. It is however more realistic to estimate this share as around 40–50 %, with an annual amount of waste of 250 and 500 tonnes corresponding to one and two units respectively.

The total amount of non-radioactive hazardous waste generated will be around 20 tonnes/year for one reactor unit and will include scrapped electrical and electronic components, batteries, coolants, solid oily waste, solvents and fluorescent tubes and light bulbs. Chemicals used in normal operation are sodium hydroxide and sulphuric acid. The hazardous waste has to be sorted, packaged and confined by the contracting company and then transported by a licensed contractor to licensed disposal place outside the NPP site. Some chemical effluents, with waste amounts strongly dependent on the technology chosen and the site-specific operations, used in process in both operating manoeuvres and maintenance operations of nuclear industry are thought to be discharged after reprocessing, always respecting the limits set by the Lithuanian and European legislations. These estimated amounts are presented in Table 6.2-1 as well.

There will be different types of waste water types that will have to be handled, filtered and processed, also including the use of suitable intermediate storage and / or drainage systems, before they are safely discharged to the lake in the outlet system or removed from the power plant site. The overall amount of waste water produced every day by the power plant in operation is roughly estimated as 350–400 m³/day for 1 unit and 750–800 m³/day for 2 units. This waste water will include sanitary water (estimated amount 50–100 m³/day), process waste water (estimated amount 240–480 m³/day), waste water used for the production of process water (estimated amount 60–120 m³/day) and waste water resulting from the raw water treatment (estimated amount 25–50 m³/day). None of these waste water types and amounts will be discharged to the lake without being treated and properly disposed of following the national and European regulations. A waste water system plant has to be studied and implemented for this purpose, as well as a storm sewer system. Sewage water will be managed in accordance with the requirements of the "Regulation on Sewage Management" (*State Journal, 2007, No. 110-4522*). Surface water will be managed in accordance with the requirements of the "Regulation on Surface Water Management" (*State Journal, 2007, No. 42-1594*).

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 basis of the waste management of the new plant is to utilise existing solutions at the INPP (designed or already in use) to the greatest possible extent. The suitability of the existing radioactive waste management and storage facilities for the management and storage of the radioactive waste from the new NPP is evaluated in Section 1.8. The capacity of planned disposal facilities can be extended when it is necessary.

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.

Radioactive waste management program will be implemented at the new NPP. 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 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, gaseous 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 and storage methods are described. Radioactive waste impact on certain environmental components is assessed in Chapter 7.

6.2.2.1 Solid radioactive waste

Solid radioactive waste consists of spent ion exchange resins; cartridge filters; particulate filters from ventilation systems; charcoal beds; tools; contaminated metal scrap; core components; contaminated rags, clothing, paper, plastic, etc. Annual solid waste generation rates for different reactor types, which are considered as technological alternatives, are summarized in Table 6.2-2. For comparison, the annual amount of solid radioactive waste generated by one unit of the existing Ignalina NPP is ~550 m³/year (~420 m³/year/GW).

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

		For one Unit, m ³ /year	Planned number of Units	Total amount from all Units, m ³ /year	Amount per GW, m ³ /year/GW
BWR	ABWR (DCD ABWR, 2007)	~430	2	~860	~330
	ESBWR (DCD ESBWR, 2007)	~470	2	~940	~300
PWR	EPR (EPR FSAR, 2007)	~225	2	~450	~135
	APWR (DCD APWR, 2007)	~310	2	~620	~180
	AP-1000 (DCD AP- 1000, 2005)	~160	3	~480	~145
	AP-600 (DCD AP- 600, 1999)	~140	5	~600	~200
	WWER (IAEA- TECDOC-1492)	120-250	2	240-500	85-175
HWR	CANDU-6 (TQ AECL, 2008)	~40	4	~160	~50
	ACR-1000 (EIA ACR-1000, 2006)	~55	3	~165	~50

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)
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.

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;
- Incineration – produces a high volume reduction and converts the combustible radioactive waste into a form suitable for subsequent immobilization and disposal.

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.

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.

Annual liquid radioactive waste generation rates for different reactor types which are considered as technological alternatives are summarized in the Table 6.2-4.

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

		For one Unit, m ³ /year	Planned number of Units	Total amount from all Units, m ³ /year	Amount per GW, m ³ /year/GW
BWR	ABWR (DCD ABWR, 2007)	~29500	2	~59000	~22700
	ESBWR (DCD ESBWR, 2007)	~28600	2	~57200	~18500
PWR	EPR (EPR FSAR, 2007)	~8000	2	~16000	~4800
	APWR (DCD APWR, 2007)	~7000	2	~14000	~4100
	AP-1000 (DCD AP- 1000, 2005)	~2500	3	~7500	~2300
	AP-600 (DCD AP- 600, 1999)	~2300	5	~11500	~3800
	WWER (IAEA- TECDOC-1492)	~15000	2	~30000	~11000
HWR	CANDU-6 (TQ AECL, 2008)	~14000	4	~56000	~19000
	ACR-1000 (EIA ACR-1000, 2006)	n/a	3	n/a	n/a

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. 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.

Like any nuclear power plant, the new NPP will discharge certain amounts of liquids which contain radionuclides into the environment. Radioactive effluents, i.e. technical water, household waste water (which had no contact with radioactive materials) and surface water (i.e. storm water) may be released into the environment if the activity of the radionuclides does not exceed the limit activity, determined in the permission issued by the Lithuanian Ministry of Environment.

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.

6.2.2.3 Gaseous radioactive waste

The possible sources of gaseous radioactive releases include the following:

- leakage from the coolant, the moderator systems or the reactor itself;
- degasification systems for the coolant;
- condenser vacuum air ejectors or pumps;
- the exhaust from turbine seal systems;
- activated or contaminated ventilated air.

Emissions into the atmosphere can include noble gases, iodine, aerosols, tritium and carbon-14. Atmospheric emissions occur through the vent stack. Gaseous waste processing systems ensure the removal of the radioactive contaminants such as aerosols, noble gases and iodine from off-gases under both normal and abnormal conditions to levels permissible to discharge effluents within the discharge limits set by the Ministry of Environment. These systems include an exhaust active ventilation system with delay, iodine and aerosol filters.

Radioactive materials may be released into the environment only after the permission for discharges of radioactive substances to the environment is obtained. This permission is issued by the 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 releases into the environment from different reactor types during normal operation are described in Section 7.2.2.

6.2.2.4 Spent nuclear fuel

After SNF is removed from the reactor core, it is stored in storage pools for a certain decay 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. As can be seen, about ten times higher amount of SNF is generated in HWR reactors. Such higher amount is due to the fact that HWRs use natural or low enriched nuclear fuel. For comparison, the annual SNF generation at one unit of the existing Ignalina NPP is 50–70 tonnes_{HM}/year (38–54 tonnes_{HM}/year/GW). Such range of amount is due to the fact that nuclear fuel with different initial enrichments (from 2.0 % to 2.8 %) is used in the existing Ignalina NPP.

Table 6.2-5. Annual generation of SNF.

		For one Unit, tonnes _{HM} /year	Planned number of Units	Total from all Units, tonnes _{HM} /year	Amount per GW, tonnes _{HM} /year/GW
BWR	ABWR	26.4	2	52.8	~20
	ESBWR	30.2	2	60.4	~20
PWR	EPR	23.4	2	46.8	~15
	APWR	27.4	2	54.8	~16
	AP-1000	17.6	3	52.8	~16
	AP-600	10.0	5	50.0	~17
	V-392	21.4	3	64.2	~21
	V-448	27.3	2	54.6	~20
HWR	EC-6	92.4	4	369.6	~132
	ACR-1000	53.5	3	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. Presently reprocessing of SNF is prohibited by Lithuanian legislation.

The existing national Strategy on Radioactive Waste Management (*State Journal, 2002, No. 15-567*) foresees several options to be investigated prior the final decision will be taken:

- Possibility to dispose of the SNF in a national deep geological repository;
- Possibility to dispose of the SNF in a regional deep geological repository;
- Possibility to transfer and dispose of the SNF in other countries;
- Possibility to safe store the SNF for 100 years and more.

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.

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. As the radioactive decay of fission products, which are the main contributors of ionising irradiation, occurs with time, the intensity of radiation reduces to the values when SNF could only afterwards be safely transferred to a dry storage facility.

The decay of the fission products also generates thermal energy which must be removed to prevent fuel rod heat up and risk of cladding failure, leading to release of fission product gases. Therefore, submerging the SNF under water within the storage pool also assists in controlling fuel bundle temperatures through convective cooling.

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.

6.3 DECOMMISSIONING

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 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 m³) 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 m³ 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 and methods

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*).

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

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. 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.

6.3.3 Decommissioning 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 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 cost would be to optimize the design of the systems and structures for eventual decommissioning.

6.3.4 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*).

6.3.4.1 System design

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.

6.3.4.2 Facility design

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*).

6.3.4.3 Summary key factors

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:

- 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 when a reactor is eventually retired.