Hungary’s national program
for spent fuel and radioactive waste management

August 2016

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Glossary of abbreviations and terms

Fund	Central Nuclear Financial Fund
ALARA principle	An acronym from the English term "As Low As Reasonable Achievable", meaning that the radiation exposure is kept low as reasonably achievable.
ALFRED	Name of the reactor to demonstrate the operability of lead-cooled fast reactor technology.
ALLEGRO	Name of the reactor to demonstrate the operability of gas-cooled fast reactor technology.
Nuclear Act	Act CXVI of 1996 on nuclear energy
BAF	Boda Claystone Formation (BCF)
BME NTI	The Budapest University of Technology and Economics, Institute of Nuclear Technology, license holder of the training reactor.
Budapest Research Reactor	The Hungarian Academy of Sciences, Research Centre for Energy Sciences, Research Reactor.
ERU	Acronym from the English term "Enriched Reprocessed Uranium reprocess", which stands for the re-enriched fuel produced from the uranium separated during the reprocessing.
FHF technology	A liquid waste processing technology used in the Paks Nuclear Power Plant to reduce the volume of liquid waste (LRWTT).
GFR	An acronym created from the English term "Gas-cooled Fast Reactor" (GCFR), meaning a gas-cooled fast reactor, which is one of types of the fourth generation reactors.
Directive	COUNCIL DIRECTIVE 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste
ITT	Isotope Information Association (an association of local governments working in the environment of RWTDF)
KGYK	Paks Nuclear Power Plant (NPP), Maintenance Training Center
KKÁT	Interim Spent Fuel Storage (ISFS)

Central Register	A central register maintained by the Hungarian Atomic Energy Authority pursuant to the provisions of Decree 11/2010 (III. 4.) KHEM on the order of registration and verification of radioactive materials, as well as the related data supply.
MOX	An acronym created from the "Mixed Oxide Fuel" English term, meaning the mixed fuel (uranium and plutonium) produced from the plutonium separated during reprocessing.
MTA EK	The Hungarian Academy of Sciences, Energy Research Centre, license holder of the Budapest Research Reactor (HAS CER).
NAH well	Paks Nuclear Power Plant, a tube well for the interim storage of high level radioactive waste.
NRHT	National Radioactive Waste Repository establishment on the Bátaapáti site (NRWDF)
NyMTIT	Western Mecsek Social Information and Regional Development Association of Local Governments (a local government association operating in the area of research of the deep geological storage site)
OAH	Hungarian Atomic Energy Authority (Nuclear Energy Authority) as a government agency (HAEA).
Training reactor	Budapest University of Technology and Economics, Institute of Nuclear Technology, Training Reactor
PUREX	An acronym created from the English term "Plutonium and Uranium Recovery by EXtraction", which is the most widely used method of reprocessing of spent fuel.
REMIX	An acronym created from the English term "REgenerated MIXture of U, Pu oxides", a fuel type under development to be produced from recycled uranium and plutonium.
RHFT	Radioactive Waste Treatment and Storage Facility on the site near Püspökszilágy (RWTDF)
RHK Kft.	Radioactive Waste Management Nonprofit Limited Liability Company
TEIT	Social Association for Control, Information and Municipal Development (an association of local governments operating in the environment of ISFS)

TETT	Social Control and Information Association (an association of local governments working in the environment of NRWDF)
t_{HM}	Spent fuel mass in tonnes of heavy metal.
V4	The Visegrad Four: Czech Republic, Poland, Hungary and Slovakia.
V4G4	The organization of the V4 countries for the coordination of research of 4th generation reactors,
VVER-440/213	Water-cooled and water-moderated power reactor of Russian-design. Paks Nuclear Power Plant operates with such reactors. The original capacity was 440 MW_e.
VVER-1200	Water-cooled and water-moderated power reactor of Russian-design. Rated capacity of approx. 1200 $MW_{e.}$ The new nuclear power plant units to be built on the Paks site belong to this family of reactors.

1 Preface

In its Article 4 the Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste (hereinafter the Directive) provides that the Member States shall establish and maintain a national policy on the management spent fuel and radioactive waste. The Hungarian Parliament in accordance with the above regulations, in its resolution 21/2015. (4 May 2015) OGY adopted a national policy document on the management of spent fuel and radioactive waste (hereinafter referred to as national policy).

The national policy summarizes the principles applicable to the management of spent nuclear fuel and radioactive waste. Most of these principles were promulgated in the Hungarian legal regulation - mainly in the Act CXVI of 1996 on nuclear energy (hereinafter: Atomic Act) and its implementing decrees - before the adoption of a national policy, but have also been recast according to the requirements of the Directive in a systematic manner. The national policy formulates the policies for closing the fuel cycle, the management of radioactive waste and the decommissioning of nuclear installations as the boundary conditions of the national program, moreover, the requirements and methods for public participation in decision-making, i.e. the policy of public disclosure are also presented.

The Directive provides in Article 11 that every country shall have a national program, which shall be kept up to date. Article 12 stipulates that the national program shall contain the following:

(a) the overall objectives of the Member State’s national policy in respect of spent fuel and radioactive waste management;
(b) the significant milestones and clear timeframes for the achievement of those milestones in light of the overarching objectives of the national programme;
(c) an inventory of all spent fuel and radioactive waste and estimates for future quantities, including those from decommissioning, clearly indicating the location and amount of the radioactive waste and spent fuel in accordance with appropriate classification of the radioactive waste;
(d) the concepts or plans and technical solutions for spent fuel and radioactive waste management from generation to disposal;
(e) the concepts or plans for the post-closure period of a disposal facility’s lifetime, including the period during which appropriate controls are retained and the means to be employed to preserve knowledge of that facility in the longer term;
(f) the research, development and demonstration activities that are needed in order to implement solutions for the management of spent fuel and radioactive waste;
(g) the responsibility for the implementation of the national programme and the key performance indicators to monitor progress towards implementation;
(h) an assessment of the national programme costs and the underlying basis and hypotheses for that assessment, which must include a profile over time;
(i) the financing scheme(s) in force;
(j) a transparency policy or process as referred to in Article 10;

(k) if any, the agreement(s) concluded with a Member State or a third country on management of spent fuel or radioactive waste, including on the use of disposal facilities.

The national program was drawn up in accordance with the above requirements, taking into account the baseline reference status as of 1 January 2015.

The national program was prepared in accordance with the provisions of Article 12 of the Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste and Article 5/C of the Atomic Act.

Conducting a strategic environmental assessment procedure

The national programme is subject to the scope of *Directive 2001/42/EC of the European Parliament and of the Council on the assessment of the effects of certain plans and programmes on the environment* (the 'SEA Directive') and of the *protocol adopted in Kiev on 21 May 2003 on strategic environmental assessment, connected to the convention adopted in Espoo on 26 February 1991 on environmental impact assessment in a transboundary context* (the 'Kiev Protocol'); therefore, *pursuant to Section 2(ba) of Government Decree 2/2005 of 11 January 2005 on the environmental assessment of certain plans and programmes*, *the developer initiated and conducted a strategic environmental assessment procedure in 2015 and 2016*.

In compliance with the legal requirements, it was a two-step procedure. In the first part (in the second half of 2015) the developer collected the comments from the bodies specified by legislation, responsible for environmental protection (Annex No 3 to Government Decree 2/2005 of 11 January 2005) on the thematics required for the elaboration of the environmental assessment. Afterwards, the developer drew up the environmental report for the national programme on the basis of the thematics adopted and of Annex No 4 to Government Decree 2/2005 of 11 January 2005.

Pursuant to the international and EU legal requirements, significant transboundary environmental and health impacts were also assessed under the procedure (in the first half of 2016), according to the requirements of *Government Decree 132/2010 of 21 April 2010 on the promulgation of the protocol adopted in Kiev on 21 May 2003 on strategic environmental assessment, connected to the convention adopted in Espoo on 26 February 1991 on environmental impact assessment in a transboundary context*, of the SEA Directive and of Government Decree 2/2005 of 11 January 2005. By doing so, Hungary ensured the right of Austria, Slovakia, Ukraine, Romania, Serbia, Croatia and Slovenia to participate, as potentially affected parties, in the strategic environmental assessment procedure exploring the transboundary environmental impacts of the national programme.

According to the relevant legal regulations, **Hungary has taken into account the comments received during the procedure in the decision-making under the programme and it will make the national programme accessible for the public and for the commenting bodies; furthermore, it will send the programme to the parties participating in the international phase of the procedure with no delay.**

2 Objectives, general principles, responsibilities formulated by the national policy, the aim and boundary conditions of the national program

The principles to be applied to radioactive waste and spent fuel management and decommissioning of nuclear facilities are summed up in the national policy.

Chapter 2.1 describes those of the principles, which are relevant to the drawing up and the practical implementation of the national program.

Chapter 2.2 presents the responsibility areas related to activities under the national program, while Chapter 2.3 summarizes the aim of the national program and some of the policies comprising its boundary conditions.

2.1 General principles

1) **Protection of human health and the environment:** Nuclear energy should be used only in such a way so as not to jeopardize human life, the health, living conditions for current and future generations, the environment and material goods over and above a risk level socially acceptable – and necessarily undertaken even in other economic activities. The general condition of application of nuclear energy is that the social benefits it provides are greater than risk to which the population, the workers, the environment and material assets are exposed.
2) **Primacy of security:** Security has priority over any other aspect in the application of nuclear energy, i.e. in activities under the national program (radioactive waste and spent fuel management and decommissioning of nuclear facilities).
3) **Burdens passed on to future generations:** The safe management of radioactive waste and spent fuel must be ensured in the application of nuclear energy in such a way that no heavier than acceptable burden is transferred to future generations.
4) **Minimizing the production of radioactive waste:** The user of atomic energy is obliged to ensure that the amount of radioactive waste produced through its activities should be of the lowest level practicable.
5) **ALARA principle:** The acronym from the English term "As Low As Reasonable Achievable" implies that the radiation exposure is kept as low as reasonably achievable.
6) **The final disposal of radioactive waste generated in our country:** The radioactive waste produced in Hungary, and the high level radioactive waste resulting from the reprocessing of spent fuel resulting from the fuel use in Hungary should basically be permanently disposed of in Hungary, unless at the time of delivery an agreement is in force with a country undertaking the final disposal – in accordance with the criteria set by the European Commission, - under which radioactive waste produced in Hungary can be transported to the radioactive waste repository of that country for final disposal.

7) **"Polluter pays" principle:** The cost of managing spent fuel and radioactive waste shall be borne by the entity, in which these materials were created.

2.2 Scope of responsibilities, organizational framework

The Hungarian state shall assume ultimate responsibility for the management of spent fuel and radioactive waste generated in Hungary, with the exception of sealed radioactive sources not in use, if it had been returned to the dealer or the manufacturer and the spent fuel of the research reactor, if shipped to a country where the under the applicable international agreements fuel for research reactor is sold or produced (see Chapter 4.2).

When transporting the spent fuel and radioactive waste for the purpose of processing and reprocessing, respectively, from Hungary to a Member State of the European Union or to third countries, the Hungarian state shall continue to bear the ultimate responsibility for the safe final disposal of these materials, including also the waste generated as by-product. If Hungary uses the facility of a third country for the management of spent fuel and radioactive waste, then, before using the service shall ascertain, *inter alia*, that the country providing the service, has such programs and facilities, the high-level security objectives of which are equivalent to those defined in the Directive.

The primary responsibility for safety rests with the license holder of the facility or activity causing the increased radiation risk. This is a general principle applicable for all users of nuclear energy, including license holders involved in the management of spent fuel and radioactive waste.

The use of nuclear energy may only take place in the manner defined by the legislation and under regulatory supervision. The Hungarian Atomic Energy Authority (hereinafter HAEA or nuclear supervisory body) was established in Hungary, which is independent of the administrative agencies interested in the promotion and application of nuclear power, and it the supervisory authority of nuclear facilities and radioactive waste repositories.

In accordance with the Atomic Act, the Government appoints an agency to carry out the tasks related to the preparation of the national policy and national program for the management of radioactive waste and spent fuel, the final disposal of radioactive waste, as well as the interim storage of spent fuel, the closing of the nuclear fuel cycle and the decommissioning of nuclear facilities. Authorized by the Government, the HAEA established for the implementation of the above tasks on 2 June 1998, the Public Benefit Company for Radioactive Waste Management, which was transformed on 7 January 2008 into the Radioactive Waste Management Non-profit Limited Liability Company (hereinafter: PURAM Ltd..). So with this an independent body was established in Hungary, responsible for the management of radioactive waste, whose functions and responsibilities are defined by law.

On the basis of the Atomic Act the Central Nuclear Financial Fund (hereinafter referred to as: Fund) was created, which provides funding for the management of radioactive waste and spent fuel, and for the tasks related to the decommissioning of nuclear facilities, as a separated state financial fund (see details in Chapter 11). The costs of managing spent fuel and radioactive waste are to be borne by whom these materials are produced – through making payments to the Fund. The Fund Manager is the minister responsible for overseeing the nuclear supervisory body appointed by the Prime Minister (currently the Minister for National Development).

In the series of activities for the management of radioactive waste, the responsibility is shared as follows:

- All the license holders with activities leading to the production of radioactive waste, are responsible for all management steps until its handover - including but not limited to the collection, volume reduction, conditioning, packaging - as well as ensuring that the waste handed over satisfies the relevant waste acceptance requirements.
- The responsibility of PURAMLtd. after receipt covers the additional management steps related to radioactive waste, up to and including the final disposal.

2.3 The aims and boundary conditions of the national program

The primary goal of the program is, in addition to the implementation of national principles and boundary conditions established by the national policy, include the presentation of plans and technical solutions - and of their financing - for the management of all spent fuel and radioactive waste generated on the territory of the country, from the stage of generation until final disposal. From among the general principles of the national policy, the ones most fundamental for the implementation of the national program, are listed in Chapter 2.1.

The policies concerning the closing stage of the nuclear fuel cycle as well as decommissioning are presented below as the national boundary conditions.

2.3.1 Policy for the closing stage of the nuclear fuel cycle

A final decision is not yet necessary to be made for the closing stages of the nuclear fuel cycle of the energy reactors, but it should be stated that the country needs to address the management of high level radioactive waste regardless of the method of closing the fuel cycle. Based on current research the deep geological repository is the most suitable option.

The policy for the closing stage of the nuclear fuel cycle - the concept of "progressing carefully” - means that the open fuel cycle – i.e. the direct disposal of the spent fuel originating from nuclear power plant in this country – is determined as a reference scenario, which provides the basis of the relevant cost estimates concerning the currently operating four units. In the field of closing the fuel cycle the domestic and international developments should be monitored (carefully), and if necessary, they must be incorporated into the cycle closing policy cycle and progress must be made regarding the selection of the deep geological storage site at the same time (progress).

Concerning the spent fuel not originating from nuclear power plant in our country, the fuel cycle closing policy makes use of the contract option to return it to Russia (see: Annex 2 [2]), so that the secondary wastes of fuel processing remain in Russia.

2.3.2 Policy for the management of radioactive waste

The final disposal of low and medium-level radioactive waste generated in Hungary is to be implemented in radioactive waste storage facilities established in our country. The high-level radioactive waste disposal must be solved in a repository established in a stable deep geological formation in Hungary. The primary consideration in the selection of storage site as well as in the construction of the repository shall be that the site, the bedrock and the technical solutions adopted – matching the properties of the deposited waste - jointly provide isolation of the waste from the living environment, until the required period of time.

2.3.3 Policy for the decommissioning of nuclear facilities

The license holders are required to provide a plan for the decommissioning nuclear facilities, its regular review and updating as necessary to follow changes in the regulatory requirements and the development of technology. The decommissioning plan should contain, in line with the national program, the decommissioning timetable - if necessary the period of protected conservation - and the final state of decommissioning adjusted to the long term reclamation concepts of the site.

If a site has more nuclear facilities, having different licenses, all the nuclear facility specific decommissioning plans must also consider the interactions and relationships between the nuclear facilities.

3 Classification, generation and inventory of radioactive waste

In Hungary, radioactive substances and ionizing radiation have been widely used from the middle of the last century in medicine for diagnostic and therapeutic purposes as well. Modern imaging equipment and radiation-sterilized medical devices are now essential methods and tools of modern medical practice. The ionizing radiation is used to destroy effectively the harmful microorganisms in the case of food packaging materials and spices imported from remote tropical countries. The industrial radiography procedure has become an everyday procedure applied to explore material defects in machinery and component parts to prevent breakdowns caused by defects in materials.

The best-known and most important area of application of nuclear energy is for electricity generation. In Hungary, four energy reactor units operate, each with a rated electrical output of 500 MW at the Paks Nuclear Power Plant site, which accounts for about 36% of the domestic electricity consumption over a long time scale.

The Parliament in 2014 adopted the Act II of 2014 on the promulgation of *the Convention on cooperation in the field of use of nuclear energy for peaceful purposes between the Government of Hungary and the Government of the Russian Federation* (the Convention) (hereinafter Act II of 2014, see Annex 2 [3]). Nuclear power has, therefore, an important role in the future of long-term electricity supply of Hungary by building two new nuclear units on the Paks site in accordance with the Convention.

The Research Reactor of the Energy Research Centre of the Hungarian Academy of Sciences (hereinafter: Budapest Research Reactor) and the Training Reactor of the Institute of Nuclear Technology of the Budapest University of Technology and Economics (hereinafter: BME) (hereinafter: Training Reactor) serve important research and educational purposes. On the site of the Budapest Research Reactor significant production of isotopes is conducted for use in medicine and industry.

In summary, it can be established that the use of radioactive substances and ionizing radiation is for the benefit of society, and contributes significantly to the national economy's performance. However, it must be taken into account that the above applications are associated with the generation of radioactive waste, the safe and final disposal of which represent tasks occurring at the national level.

3.1 Classification of radioactive waste

Taking into account the radiation and contamination conditions, the users of nuclear energy divide their facilities into controlled and supervised areas. As a general principle, the waste generated in the controlled area shall be treated as radioactive until the contrary is proved by measuring. This is important because Hungarian law allows the release of very low activity substances from official control. This is possible if the annual individual dose originating from the recycling of materials and their management as non-radioactive waste, respectively, does not exceed 30 μSv effective dose.

Based on the definition of the Atomic Act, radioactive material not intended for further use is called radioactive waste, which cannot be managed as ordinary waste on the basis of radiation protection features, that is, it cannot be released.

The classification of radioactive waste can be carried out as follows according to the activity and half-life characteristics of the isotopes they contain.

Such radioactive waste can be classified as low and medium-level radioactive waste, which has a negligible heat generation during the disposal (and storage).[1]

a) Such low and intermediate level radioactive waste can be classified as short-life in which the half-life of the radionuclides is 30 years or less, and contain only a limited concentration of long-life alpha-emitting radionuclides.

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[1] The Hungarian Standard 14344-1: 2004 defines a heat development value (2 kW / $m^{3)}$, which is regarded as significant for the interim storage and / or final disposal, so it must be taken into account.

b) The low and intermediate level radioactive waste has long life, in which the half-life of the radionuclides and / or the concentration of alpha-emitting radionuclides exceed the limits for short-life radioactive waste.

The radioactive waste is classified as high-level, the heat production of which must be considered during the planning and operation of storage and disposal 1.

The currently effective national legislation does not include the category of very low level waste, which in turn is present in the International Atomic Energy Agency's waste classification system. Several fundamental studies were completed to show the circumstances and requirements under which it might be appropriate to introduce the very low level waste category in Hungary. The analyses prepared so far must be summarized, under which the necessary legislative amendments can be initiated and the concept for the final disposal of the very low-level waste can be elaborated - taking into account the principle of proportionality (graded approach). After the development of the concept, the national program should be expanded with this area.

3.2 The users of nuclear energy – the "waste producers"

The following chapters review and characterize, in a unified structure, the facilities and activities that contribute to the generation of radioactive waste. The expected range of their operation time, the amount of radioactive waste storage generated in the course of their operation so far are presented and their place of storage is briefly discussed as well. For each facility and / or sector involved in waste production the annual aggregate volume of radioactive waste is stated.

3.2.1 The time horizons of operating the facilities

In the Paks Nuclear Power Plant the first unit was commissioned into service in 1982, the second in 1984, the third in 1986 and the fourth in 1987. Therefore, on the site today a total of four units type VVER- 440/213 are in operation. The extension of service life of the nuclear power plant from 30 years to 50 years is under way (the authorization has already been granted by the nuclear oversight body for the run time extension of units 1 and 2, concerning the other units the decision is expected in the future), therefore, the fourth unit of the nuclear power plant is expected to be stopped by the operator in 2037. With respect to the national program the service life of 50 years has been taken into account as the reference case for the four units in operation today.

Pursuant to Act II of 2014 two new nuclear power plant units will be built on the Paks site. The two units type VVER-1200 type are expected to be commissioned into service in 2025 and 2026, respectively, with a planned operating life of 60 years.

The Budapest Research Reactor was built in 1959 and was shut down in 1986 and until 1992 a full reconstruction was carried out. After the conversion, the new reactor was granted a 30-

year operating license, which is valid until 2023. The life of the research reactor may be extended with ten years, up to 2033, the technical conditions make this a realistic option. Taking into account the current rate of use, the available fuel ensures the operation of the reactor until 2019. During the preparation of the national program as a reference case, the operation of the Budapest Research Reactor until 2023 was considered.

The Training Reactor operated by the Institute of Nuclear Technology of the Budapest University of Technology and Economics (hereinafter: BME NTI) was started up in 1971. The expected operating time of the Training Reactor is not yet defined. The parts and components of relevance to the service life are interchangeable or renewable. The renewal of the operating license of the facility will be initiated with the nuclear oversight body by the license holder during the next Periodical Safety Review scheduled for 2017. If, based on the results of the Periodical Safety Review, the competent authority extends the operating license of the Training Reactor with 10 years, the time of the final shutdown may be 2027. This date was taken into account in the national program as a reference case. However, it should be emphasized that this is not a date set with the consideration of technical, aging and radiation safety, nuclear aspects. If the replacement of certain technical equipment of the Training Reactor takes place by that date, then - possibly with a fuel assembly change - the reactor is expected to be operated for several decades to come. The relevant decision should be taken in the future, in which it is important to take into consideration the following:

- Currently the Training Reactor has a central role in the national and international nuclear training, its operation, therefore, may be needed in the longer term.
- As the Hungarian Paks NPP will continue to operate for decades, new nuclear power plant units will be established and the decommissioning and radioactive waste management programs have time horizons beyond the above timeframes, therefore, the education of new generations of nuclear specialists and special training will be required for a long time to come.

The above considerations are valid for the case of the Budapest Research Reactor as well, which ensures the scientific and research background for the nuclear industry. Decisions on the service life of the Budapest Research Reactor and the Training Reactor are not subject of the present national program, the assumptions regarding service life have relevance to the decommissioning schedule and the estimations of the volume of radioactive waste or spent fuel to be generated.

3.2.2 Generation of radioactive waste in the Paks Nuclear Power Plant

3.2.2.1 Sources and management of radioactive waste

During operation of the Paks NPP solid and liquid radioactive wastes are generated, and arrangements should provide for their collection and management.

The major sources for low and intermediate level solid radioactive waste include protective clothing, equipment, tools, plastic film becoming contaminated during operation and maintenance; as well as the contaminated or activated equipment, piping, heat insulation, etc. removed from the operating facility. In addition, the volume of solid waste is also augmented by sludge and debris, scrap metals, cables from the architectural adjustments.

The solid wastes are separately collected in view of the subsequent treatment options. Most of the radioactive waste collected in bags are the used individual and additional protective equipment obligatory in the controlled area. A variety of used parts, components, metal waste and contaminated tools, which cannot be placed in plastic bags because of their weight or size, are collected in barrels of 200 liters capacity.

The volume reduction of compactable radioactive waste takes place in a 500 kN press, during which the volume of waste treated is reduced, on the average, to one-fifth. The non-compacted radioactive waste is put in 200 liters barrels, with the optimal utilization of the volume. The resulting active sludge is settled in 200-liters metal drums and then their liquid content is removed.

After the treatment steps mentioned above, the solid radioactive waste is put into interim stored on the site of the nuclear power plant. The low and intermediate level wastes are mostly put into 200-liters barrels for transfer to the interim storage locations, while for the storage of high level radioactive waste tube wells are used.

Liquid radioactive waste is mainly produced from the cleaning of water in the primary circuit and from the decontamination of rooms and equipment.

The resulting small amounts of contaminated oil are collected in 200-liters metal drums, then the radioactive isotopes are removed via gravity filtration through diatomaceous earth layer, and after verification the decontaminated oils are released and treated as inactive waste.

The water-based liquid wastes produced in the NPP’s primary circuit are collected by a special channel system for transfer to the drainage system. The collected drainage liquid after settling, mechanical filtration and chemical treatment is concentrated through evaporation.

The residual evaporation concentrates (evaporation residue) of spent ion exchange resins and evaporator acid solution, and – in 200-liters barrels – the oily diatomaceous earth arising from the treatment of contaminated oils are put into interim storage in the controlled zone of the NPP in separate tanks.

During operation of the NPP, on an annual basis relatively small quantities (5 m^3 / year) of high-level radioactive waste are generated, [2] and put into interim storage on the site of the nuclear power plant, in dedicated tube wells. The amount of such waste was 100.6 m^3 on 01/01/2015. Until the end of the service life, the generation of a further 115 m^3 of high-level

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[2] In the operational practice of Paks Nuclear Power Plant, with respect to radiation protection criteria, waste representing a surface dose rate greater than 10 mSv / h is classified as " high level" waste. This waste is managed during decommissioning, they will be re-classified at that stage, and it will be then decided which of them will be placed in deep geological repository. Based on these considerations the quantities stated for the high level operating waste of the nuclear power plant can be considered as a conservative upper estimate.

waste is to be expected (this amount already includes the high level waste produced during the operation failure of Unit 2). During the 50-year service life 215.6 m^3 high activity waste is expected to be produced in total, it is planned to collect the waste in containers and then concrete is poured in for final disposal in the course of decommissioning.

The available storage capacity of the Paks Nuclear Power Plant, as well as the amount of radioactive wastes stored as of 01/01/2015 are shown in Table 1.

Table 1: Paks Nuclear Power Plant, the available storage capacity and the amount of radioactive waste stored on 01/01/2015

Waste type			**Capacity**	**Stored volume**
Low and medium-level radioactive waste	Liquid (in tanks)		10,020 m^3	8,200 m^3
	Solid	200 lit. drums	10,741 pcs	9,129 pcs
		Large size waste	800 m^3	-
High-level radioactive waste (in tube wells)			222.8 m^3	100.6 m^3

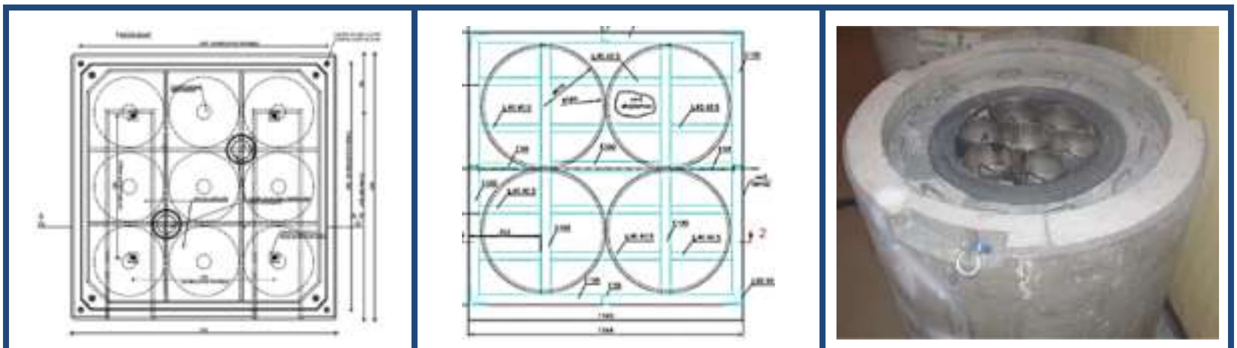
In order to drastically reduce the volume of liquid waste, the liquid waste processing technology (hereinafter: LRWTT technology) was put into operation in the Paks Nuclear Power Plant. With the operational application of this technology, the evaporation residue representing most of the liquid radioactive waste - after removal of cesium and cobalt isotopes, as well as the recovery of boric acid content - will be discharged after inspection, together with the other waters from the primary circuit authorized for discharge. Boric acid recovered in the form of borax is released as inactive hazardous waste for disposal. During processing, secondary radioactive waste is produced (cobalt recovery post-filter, cesium filter column, etc.), the interim storage of which takes place in 200 lit. drums or special containers.

As a result of the operational incident involving damage to nuclear fuel assemblies in Unit 2 of the Paks NPP in 2003 a number of such types of waste were generated, which were not to be encountered during normal operation. In the course of the management and recovery of the emergency situations significant amounts of spent ion exchange resin, distillation residues, decontamination solution and solid radioactive waste contaminated with alpha emitting isotopes were generated. Most of these have been collected separately and put into interim storage (decontamination solution, distillation residues, large appliances, and solid wastes). The LRWTT technology was not applied for the treatment of the evaporation residue affected by the incident.

3.2.2.2 Amount of operational of waste allocated for final disposal

A portion of the low and intermediate level solid wastes of the Paks Nuclear Power Plant was transported between 1983-1989 and 1992-1996 to the Radioactive Waste Treatment and Disposal Facility (hereinafter: RWTDF) in Püspökszilágy for final disposal. Since then, this repository accepts only radioactive waste from institutional sources (see Chapter 6.1). From the capacity of RWTDF the nuclear power plant occupied a gross volume of 2,500 m^3, this amount is stated in that storage site.

With the commissioning of the Bátaapáti National Radioactive Waste Repository (hereinafter: NRWDF) into service in 2008 the transfer of compacted radioactive generated in 1997-2007 began for final disposal. A total of 5,480 200-liters barrels were shipped to the NRWDF until 01/01/2015. Of this quantity 2,231 barrels are put into interim storage in the technological building on the surface, while 3,249 barrels have been placed into 361 reinforced concrete containers and deposited for final disposal (see Column 1 in Figure 1).



Reinforced concrete container of 2,250 mm x 2,250 mm x 1,380 mm external dimensions with 9 barrels, top view

Compact waste package of 1,346 mm x 1,346 mm x 1,032 mm external dimensions with 4 barrels, top view

Storage container of 1.7 m^3 external volume to accommodate 7 selective sorbents

Figure 1: Typical waste packages for depositing low and intermediate level waste of nuclear power plant origin (note: the individual containers are shown in diagrams with different scales)

In accordance with the waste management practice presented in Chapter 3.2.2.1, the Paks Nuclear Power Plant processes the vast majority of liquid waste by means of the LRWTT technology, resulting in significant volume reduction. Regarding the liquid radioactive waste which cannot be processed by the LRWTT technology (i.e. evaporation residue or sludge, decontamination solution originating from emergency interventions), the Paks Nuclear Power Plant is planning a cement solidification technology to be established and commissioned into service by the end of 2017. Cementing is done in steel containers tailored to the new concept of depositing in NRWDF. This may be in a form when the steel container contains only a cement paste prepared from liquid waste or the container may hold four drums (see column 2 in Fig. 1) and the cement paste only fills the empty spaces in the container - or in the case of non-compacted waste within the drums. The steel containers containing drums and waste in cement paste are called compact waste packages, which may hold from among the liquid waste streams the emergency distillation residues, sludge, decontamination solution and the evaporator acid solution; while from among the solid waste streams the compressed and non-compressed waste placed in drums. The spent ion exchange resins will be cemented in thin-walled steel containers, shown regarding the compact waste packages, at end of the service life of the units.

From among the solid wastes, the fractions of lower activity level are envisaged for direct final disposal in the NRWDF – without further conditioning and packaging – in 200-liters drums. Those pieces of large waste that cannot be cut up so that they could be placed in 200-liter drums, are put into interim storage at the Paks Nuclear Power Plant and according to the currently plans they shall be placed in larger containers to be transported into NRWDF in the stage of decommissioning. Among the solid wastes cesium and other filter assemblies are included, for subsequent depositing in specific circular storage containers (selective sorbent storage containers, see column 3 in Fig 1).

Table 2 shows the total quantity of the radioactive waste produced during the NPP's 50 years of operating time, to be deposited in the NRWDF, which does not include the amount of waste delivered previously to the RWTDF.

Table 2: The amount of the radioactive waste produced during the NPP's 50 years of operating time, to be deposited in the NRWDF

Mode of placement	Volume to be placed (m$^{3)}$
Placement in reinforced concrete containers (9 barrels / container)	995 *
Compressed solid waste in 200 liters barrels	1,129 *
Compact waste packages (4 barrels / container + active cement slurry from liquid waste)	10,538
Cemented liquid waste in thin-walled steel container	821
Cemented ion exchange resin in thin-walled steel container	1,390
Large size wastes in containers	800
Cesium selective sorbents in circular concrete container	51
Total	**15,724**

* It stands for the aggregate gross volume of barrels with 200 lit. useful volume (0.213 m^{3} / barrel).

3.2.2.3 Decommissioning wastes of the Paks Nuclear Power Plant

During the decommissioning and demolition works of the facility relatively large amounts of radioactive waste generation is to be expected. During decommissioning waste will be collected separately. Separate collection considers material grades, taking into account the physical and chemical characteristics, the mode and the expected level of radioactive contamination as well.

Considering the decommissioning policy of the Paks Nuclear Power Plant - which provides for the primary circuit to be conserved with protection for 20 years and subsequent decommissioning - the preliminary decommissioning plan determined the amount of radioactive waste produced during the demolishing of the nuclear power plant, which the summarized in Table 3.

Table 3: The total number and volume of radioactive packages produced during the demolition of the Paks Nuclear Power Plant earmarked for final disposal

Waste Category	DEFERRED DECOMMISSIONING		
	Number of 1.8 m^3 containers (qty.)	Number of 3.6 m^3 containers (qty.)	Total Volume ($m^{3)}$
Low and medium-level waste	9,147	2,846	**27,044 ***
High-level waste	40	0	**73**
Total	9,187	2,846	**27,117**

* In Hungary, the very low level waste category has not yet been introduced, the percentage of decommissioning waste that would fall into this category was estimated based on international experience. The analyses showed that little more than 80% of the decommissioning wastes could be a very low-level waste.

Thin-walled steel containers of ~ 1.8 m 3 volume, or twice the size of this version, used for operational waste, are envisaged for the final disposal of the waste generated during the decommissioning, in order to be optimally placed in the NRWDF.

3.2.3 Generation of radioactive waste at the Budapest Research Reactor

Low and intermediate level solid radioactive wastes typically arise from two sources during the normal operation of the Budapest Research Reactor:

- active in the aluminium capsule resides in the course of isotope production;
- as well as protective equipment (gloves, shoe protectors, protective clothing, etc.) and plastic film, filter paper contaminated in the course of routine work and maintenance.

Every year around 2 m^3 solid radioactive waste is generated, which is collected in plastic bags and then compressed in manual hydraulic press – to approx. 50% of its volume – and stored in 200 liters steel sheet drums.

The slightly radioactively contaminated liquid wastewater generated during the operation is collected in two tanks of 150 m^3 each. Normally 10-20 m^3 liquid waste is produced annually from water – typically, when testing the water recirculation systems and implementing decontamination tasks -, which shall be discharged after ion exchange purification, subject to the observation of the relevant limitations.

During the operation on an annual average of approx. 100 liters of radioactive ion exchange resin is produced, and at the bottom of the liquid waste collection tanks a few cubic meters of sludge is accumulated by the end of the service life. The radioactive waste generated during the operation is transported to Püspökszilágy RWTDF for final disposal. On 1 January 2015 at the premises of the Budapest Research Reactor 2 m^3 solid radioactive waste and 0.5 m^3 radioactive waste to be solidified was stored. Until the reference date to stop the facility, considered in the national program, i.e. 2023, it is expected that less than 10 m^3 low and intermediate level radioactive waste will be produced during operation, for final disposal.

During the decommissioning of the Budapest Research Reactor approximately 260 m^3 low and medium level radioactive waste is expected to be generated.

During operation and eventual decommissioning of the Budapest Research Reactor no high-level radioactive waste is generated.

3.2.4 Generation of radioactive waste generation in the Training Reactor

Radioactive waste is generated in the building of the Training Reactor partly related to the operation of the reactor and partly during the operation of the laboratories in the building. In the following the wastes are presented classified in accordance with their typical modes of generation, quantities and form (state).

Solid radioactive waste may be generated in the Training Reactor by removing some parts or components of the reactor; due to the irradiation of samples related to education or research or their processing; when using consumable substances in the laboratory; and it can occur due to the retirement of sealed radioactive sources. The collection of compacted and non-compacted radioactive waste takes place separately in radioactive waste collection containers (plastic bags), they will be closed after the bag is full and deposited in the radioactive waste store. Solid radioactive waste is generated to the amount of 6 bags per year (up to 100 liters per bag) on the average, with the typical mass of 3-8 kg per bag. They contain the waste (plastic and glass vessels, the irradiated samples and residues from the processing thereof, rubber gloves, paper towels, etc) in the form of compressed and non-compressed "laboratory waste". The amount of waste generated to a large extent depends on the nature and volume of the teaching and research tasks of the actual school term.

The potentially radioactive liquids (from the reactor vessel, the protection water body of the irradiation channels, the sinks of the radiochemical laboratory and the chemical cabins, etc) are transferred into a monitoring tank in the reactor building through the wastewater network. A substantial part of these liquids can be discharged after radiological certification or, where appropriate, after cleaning. The solutions classified as radioactive-waste (long-life aqueous solutions, organic (non-aqueous) solutions, solutions containing hydro-fluoride) arising from the tasks performed in laboratories, are separately collected in containers in the radiochemical laboratory or in the radioactive waste store. A few liters of liquid radioactive waste is generated each year, on the average.

The radioactive waste generated during the operation is regularly shipped to Püspökszilágy RWTDF for disposal. In the Training Reactor on 1 January 2015, 145 kg of solid and 210 liters of liquid low and intermediate level waste was stored. These radioactive wastes, after compacting or conditioning - which will take place at the site of the RWTDF – will yield roughly 1 m^3 waste for final disposal. In the compilation of this National Program Training 2027 has been taken into account as the reference date for shutdown (see Chapter 3.2.1). According to the relevant estimates from the further operation of the Training Reactor and additional amount of 5-6 m^3 low and medium level radioactive waste is expected.

The decommissioning of the Training Reactor may result in a further approx. 50 m^3 low and medium level radioactive waste.

During the operation and eventual decommissioning of the Training Reactor no high-level radioactive waste is expected.

3.2.5 Production of institutional radioactive waste

The low and intermediate level radioactive waste originating from other sources than the nuclear power plant (also known as institutional radioactive waste) are also part of the volume of all the radioactive waste generated in Hungary. The institutional radioactive waste is typically generated in hospitals, laboratories and industrial enterprises, in the form of low and intermediate level waste, spent radiation sources, as well as radiation source removed from smoke detectors. Waste of institutional origin is also generated in the course of operation and future decommissioning of the Budapest Research Reactor and the Training Reactor discussed in Chapters 3.2.3 and 3.2.4, but these facilities were highlighted in separate chapters, due to their importance.

Based upon the currently available data (01/01/2015) of the central register operated by the OAH (hereinafter: Central Register) pursuant to the Decree No. 11/2010 (4 March 2010) KHEM on the order of the registration and verification of the radioactive materials, as well as the related data supply, at the moment there are nearly half thousand license holders owning radioactive material and a total of approx. 7,000 sealed sources with respect radioactive materials used in institutions in Hungary. These are radioactive materials and radiation sources still in use today, and are actually potential institutional radioactive waste that must be disposed of in the near and distant future.

According to the Central Register data nearly fifty license holders are in possession of closed- and open source of radiation, and radioactive material – not intended for further use – which has been registered as radioactive waste, with their distribution illustrated in Fig. 2. Some license holders simultaneously hold all three types, namely open and closed radiation sources and radioactive waste.

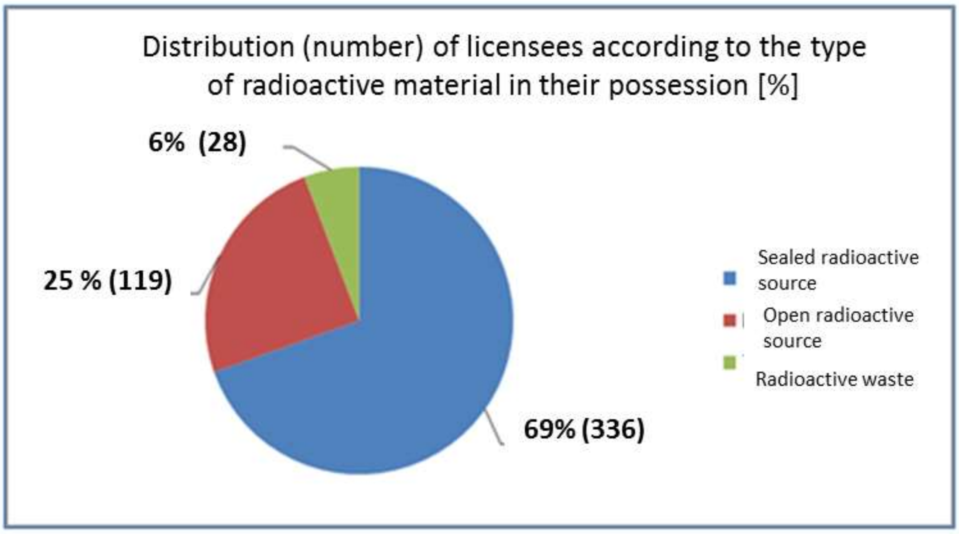


Figure 2: The distribution (number) of licensees according to the type of radioactive material in their possession [%], source: Central Register

The updating of the data base is ensured by the obligation of the license holders that in the case of sealed radioactive sources they shall supply data not later than 15 days after the change in their inventory for the Central Register, whereas in the case of open radiation sources and radioactive waste the time between two reports shall not exceed 12 months.

Figure 3 illustrates the distribution of the license holders currently registered in the Central Registry in percentage, by areas based on the use of radioactive materials. Figure 3 shows that radioactive materials used in the field of industry and health constitute the bulk of the register, so they will represent in the future the majority of institutional radioactive waste.

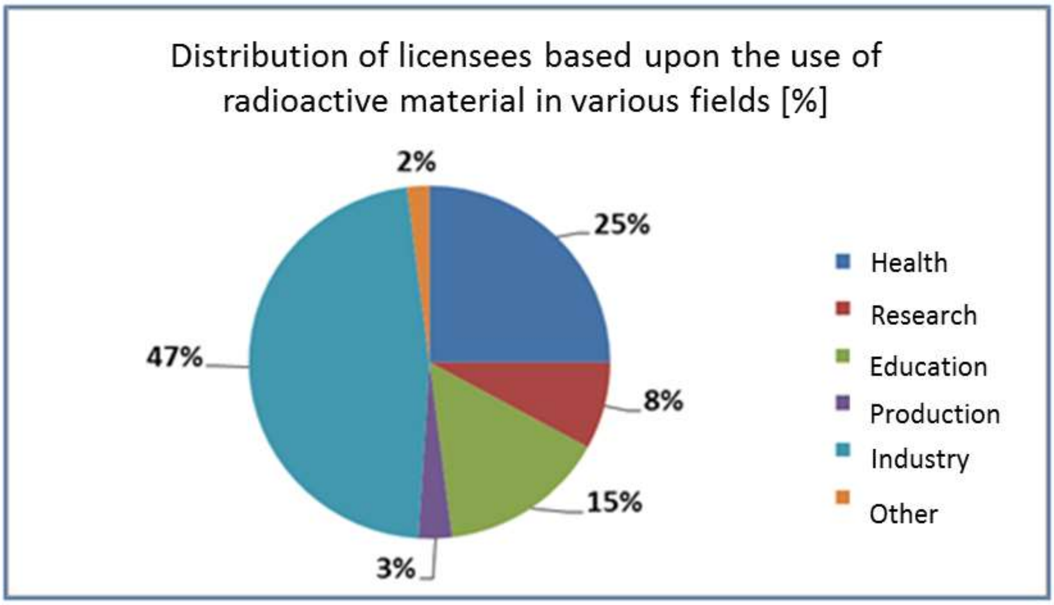


Figure 3: The distribution of licensees based upon the use of radioactive material in the various fields [%], source: Central Register

The most common radioactive isotopes to be used as sealed radioactive sources in Hungary are Co-60, Cs-137 and Am-241, but, in addition to them the use of I-125 and Ir - 192 isotopes is not negligible either. From among the sealed radioactive sources used by the license holders in terms of aggregated activity Co-60, Cs-137 and Ir-192 are the most significant isotopes. Among the open radioactive products the most frequent isotopes are the I - 125, C-14, H-3 and I-131.

The institutions, in most cases, have the resulting radioactive waste transported to the RWTDF site. With appropriate licenses, the license holders themselves may also temporarily store the radioactive waste generated by them, however, these quantities are negligible compared to the total national inventory. The Central Register shows currently nearly 30 license holders, based on the currently available data, which hold institutional radioactive waste in their registers, resulting from various applications. Figure 4 shows the distribution of institutional waste production in radioactivity percentage by the specific fields. Based on currently available data of the Central Register approx. 40 types of radioisotopes appear among these wastes, the most typical of which are the Am-241, C-14, Co-60, Cs-137 and H-3.

Based on the analysis of waste deliveries made in recent years to the Püspökszilágy RWTDF (see Chapter 6.1.3), it can be stated that on average about 10-15 m^3 of radioactive waste and 400-500 spent sealed radioactive sources are supplied annually by the license holders for interim storage or final disposal. Taking into account the closure of RWTDF in 2067 (see Chapter 6.1), is expected to until that time preparations shall be made for approximately 600 m^3 institutional waste, in excess of the quantities expected to be generated in the Budapest Research Reactor and the Training Reactor.

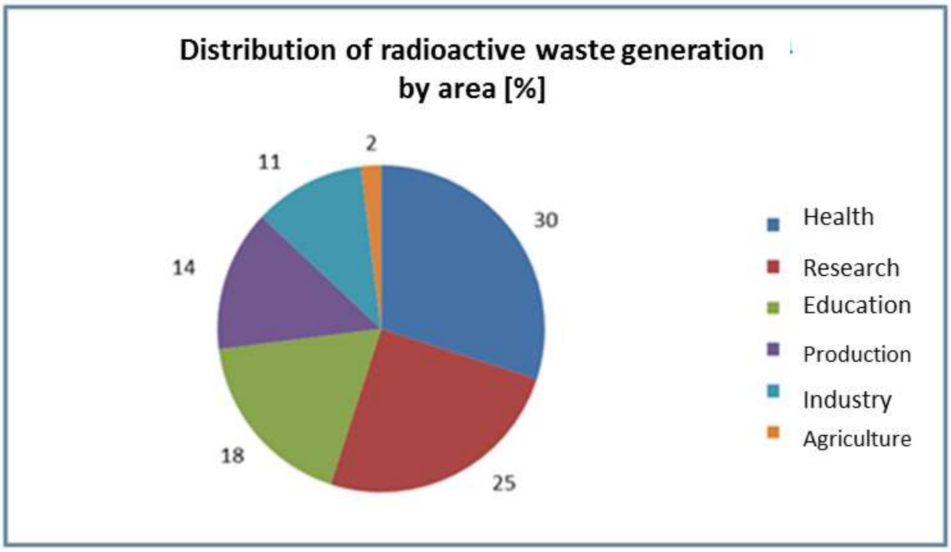


Figure 4: Distribution of radioactive waste generation by area [%], source: Central Registry

3.2.6 Radioactive wastes from the new nuclear power plant units

The major sources of solid radioactive waste from the new units will also be the protective clothing, equipment, tools, parts, plastic film contaminated during operation and maintenance; removed reactor equipment and components thereof. In addition, debris from the architectural adjustments, scrap metals, cables; contaminated and exhausted aerosol and iodine filters of the gas cleaning and air handling technological systems, the contaminated and activated equipment, piping, heat insulation removed from the operating facility also contribute to the volume of solid waste. A supercompactor (high compressive force press) will be available for the volume reduction of the compactable solid waste.

Liquid radioactive waste is produced especially in the context of cleaning the primary circuit coolant, the decontamination of the fittings, pipelines and rooms, as well as the drains from equipment, pipe sections, fittings and eventual leaks thereof. Taking of samples and laboratory activities, and wastewaters from shower in the changing rooms of the primary circuit and the special laundry will all contribute to the production of liquid waste. After evaporation the liquid radioactive waste is put into interim storage, and they are scheduled to be evaporated again to further reduce the volume before cementing.

Table 4 summarizes the amount of waste annually generated per unit in the course of operation of the projected VVER-1200 nuclear power plant and the amount of radioactive waste generated during total projected 60-year service life of the two units.

Table 4: Estimate of the amount of radioactive waste produced during the operation of the two new nuclear power plant units to be built on the Paks site

Waste type	**Annual amount generated per unit**		**Total volume for the two units over a 60-year operating period [m$^{3]}$**
	The amount of waste [m ^{3} / year]	*The amount of waste after treatment (solidification, crushing, etc.) [m ^{3} / year]*	
Low and medium-level solid	81	32	3,840
Large size, not possible to handle (resulting from maintenance / repair)	5	-	600
Cemented evaporation residue	25	20	2,400
Cemented ion exchange resins	10	8	960
Cemented sludge	0.6	0.5	60
High-level solid	0.5	-	60

The repository system used in the NRWDF was optimized for the storage of compact waste packages based on thin-walled steel container described in Chapter 3.2.2.2, so it is advisable also to take this type of waste package into account for the new units. The amount of low and intermediate level waste from the operation of two new blocks over 60 years in the last column of Table 5 must be taken as a base and the quantity for disposal must be determined as shown in Table **Hiba! A hivatkozási forrás nem található.**.

Table 5: Volume of low and intermediate level waste generated during 60 years of operation of the two new nuclear power plant units to be built on the Paks site, to be deposited in the NRWDF

Waste Package	**Waste Package Description**	**Quantity (pcs)**	**Volume [m $^{3]}$**
Compact waste package (1.8 m^3)	4 barrels of solid waste + active cement slurry	2,589	4,765
Metal Container (1.8 m^3)	Cemented ion exchange resins	533	980

Waste Package	**Waste Package Description**	**Quantity (pcs)**	**Volume [m $^{3]}$**
Barrel (200 liters)	Compressed solid waste	8,842	1,833
Large, not possible to handle (resulting from maintenance / repair)		-	600
		Total:	**8,228**

On the basis of currently available data, the decommissioning of a Russian-designed VVER-1200 pressurized water nuclear power plant may lead to the production of 16,250 m^3 very low, 2,050 m^3 low and medium level and 85 m^3 high-level radioactive waste for each unit.

3.3 The aggregated inventory of radioactive waste

In the previous chapters those facilities - and activities with respect to institutional radioactive waste – were presented, the operation and eventual decommissioning of which lead to the generation of radioactive waste.

Table 6 summarizes the inventory of low and intermediate level waste generated in Hungary. The table shows also decommissioning waste volumes from the Interim Spent Fuel Storage Facility (ISFS) operated at the Paks site (see the table displayed in Chapter 7.2). Under the current plans, the low and intermediate level waste from the nuclear power plant will be deposited in the in NRWDF established in Bátaapáti, and waste from institutional sources will be finally disposed of in the RWTDF operating in Püspökszilágy (rounded quantities for disposal are shown in Table 6). Radioactive waste arising from the dismantling of service facilities of NRWDF and RWTDF at the conclusion of storage shall also be deposited on site, but the relevant amounts are not significant, according to preliminary estimates.

Table 6: Aggregated inventory of low and intermediate level waste generated in Hungary

Source of waste	**Current volume (01/01/2015) [m^3]**	**Future amount generated [m^3]**	**Amount to deposited [m^3]**	**Final disposal**
NRWDF interim storage	475	-	1,170	NRWDF
NRWDF final storage	692	-		
Operation of Paks units 1-4	10,144	10,466	14,600 *	
Decommissioning of Paks units 1-4	-	27,044	27,100 **	
Operation of Paks units 5-6	-	8,228	8,300	
Decommissioning of Paks units 5-6	-	36,600	36,600 **	
Decommissioning of ISFS	-	100	100	
TOTAL:	**11,311**	**82,438**	**87,870**	

RWTDF final storage	4,900	-	4,900	RWTDF
Operation of Training Reactor	1	6	7	
Decommissioning of Training Reactor	-	50	50	
Operation of Research Reactor	3	10	13	
Decommissioning of Research Reactor	-	260	260	
Other Institutional radioactive waste	NA	600 ***	600	
TOTAL:	**4,905**	**926**	**5,830**	

* Due to the application of the planned volume reduction treatment technologies the resulting volume of waste to be deposited does not match the total of current and future amounts of waste produced.

** The very low level waste category does not yet exist in Hungary, but preliminary estimates suggest that more than 80% of the decommissioning wastes of the Paks Nuclear Power Plant (Paks 1-4) and 89% of the decommissioning waste of the new units (Paks 5-6) would fall into that category of waste.

*** The estimated amount to be delivered until the scheduled closing of the RWTDF in 2067.

In relation to the table 6 it is important to note that in order to ensure the necessary capacity for the disposal of institutional radioactive waste, a safety enhancement program must be carried out in the RWTDF, which also frees up storage volume (see Chapter 6.1.2). Institutional radioactive waste is expected to be generated also beyond the service life of RWTDF considered in the national program, and the final placement of which will have to be decided in the early 2060's.

The estimates of the possible quantities of very low-level radioactive waste - in particular with regard to the decommissioning waste - in any case justify that Hungary develops the optimum concept for the disposal of these wastes on the basis of the principle of proportionality. This optimization must take place taking into account the two radioactive waste storage facilities also in service today.

In addition to the management of spent fuel, high level radioactive / or long-life radioactive waste is also generated in the country that cannot be placed permanently in NRWDF or in RWTDF. This radioactive waste shall be deposited permanently in a deep geological repository to be established in Hungary in the future. The high-level and / or long-life waste inventory is summarized in Table 7.

Table 7: Inventory of high-level and / or long-life waste produced in Hungary

Source of waste	**Current volume (01/01/2015) [m^3]**	**Future amount generated [m^3]**	**Amount to deposited [m^3]**
Operation of Paks units 1-4	101	115	216
Decommissioning of Paks units 1-4	-	73	73
Operation of Paks units 5-6	-	60	60
Decommissioning of Paks units 5-6	-	170	170
Of institutional origin *	100	400	500

TOTAL:	**201**	**818**	**1,019**

* The interim storage of long-life institutional radioactive waste currently takes place on the RWTDF site.

The physical location of facilities having a significant role in the generation, interim storage and final disposal of radioactive waste is shown in Figure 5.

Figure 5: Location of the facilities playing a role in the formation and management of radioactive waste

4 Generation of spent fuel

According to the determination of the Atomic Energy Act the spent fuel is the nuclear fuel irradiated in and permanently removed from the nuclear reactor is not a waste, due to its reprocessability outside the nuclear reactor or when reprocessing is not done due to the applicable decision, it shall be classified as radioactive waste and arrangements shall be made concerning its final disposal. In this latter case, the spent fuel is considered high-level waste and shall be managed accordingly.

4.1 Radioactive waste generated in the Paks nuclear power plant

There are four VVER-440 type reactors located in the Paks Nuclear Power Plant. Each reactor produced initially 1,375 MW of thermal energy, which could produce 440 MW of electricity. Owing to a variety of secondary and primary developments now 1,485 MW thermal energy and 500 MW of electricity can be produced by each unit. The reactor core has 349 fuel assemblies. Of them, 312 assemblies are in service, which are involved only in the energy production, the other 37 pieces are so-called safety and control (control) assemblies, which consist of fuel parts and absorber parts. The characteristics of the fuel assemblies are shown in Table 8. The fuel assembly types used in the Paks NPP are described in Annex 1.

Table 8: Geometric features of the fuel assemblies of the Paks Nuclear Power Plant

Assembly features	Fuel assembly in service	Control and safety assemblies	
		Fuel parts	Absorbing part
Overall length of the assembly (mm)	3,217	3,200	2,630
The maximum distance across flats (mm)	145	145	144
Nominal weight (kg)	219	220	110
The number of fuel rods	126	126	-
Rod length (mm)	1st generation: 2,540 2nd generation: 2,601.5	1st generation: 2,540 2nd generation: 2,540	-

4.1.1 The amounts of spent fuel generated in the Paks Nuclear Power Plant

Since is commissioning into service the Paks NPP has procured 14,101 fuel assemblies and 837 absorbers. The current locations of the absorber assemblies are shown in Table 9, while those of the fuel assemblies are shown in Table 10.

Table 9: Location of the absorber assemblies purchased by the NPP so far (01.01.2015.)

Storage facility	Fresh fuel storage	Reactors	Relaxing pool	NAH wells	KGYK	Total
absorber [pcs]	51	148	108	528	2	**837**

The absorber assemblies in the spent fuel pool have safety functions, they ensure the safe operating condition (adequate sub-criticality) even in case of assemblies of enrichment at

3.82% and above[3]. In the Maintenance Training Centre (KGYK) 2 absorber assemblies are used for educational and practical tasks. Absorber assemblies not intended for further use are placed in the tube wells used for storing high-level radioactive waste (NAH wells) in the units of the nuclear power plant.

Table 10: Location of fuel assemblies purchased by the NPP until 01.01.2015

Storage facility	Fresh fuel storage	Reactors	Relaxing pools	Russian Federation	ISFS	Total
Fuel Assembly [pcs]	529	1,396	1,733	2,366	8,077	**14,101**

The fresh fuel stores hold fuel assemblies which have not operated yet. Of the 529 assemblies 48 pieces are of 1.6% or 2.4% enrichment, which are the strategic reserves, i.e. that are used only in special cases. The remaining fuel assemblies are of 4.2% enrichment.

The reactors are now in operation mainly (1,104 pieces) with fuel assemblies enriched to 4.2%. There are only 280 pieces of fuel assemblies enriched to 3.82%, but they are also removed during the refuelling cycles in 2015. Unit 3 also holds 12 pieces of fuel assemblies enriched to 4.7%, for testing purposes. The fuel assemblies of 4.7% enrichment are necessary because after 2015 the12-month campaign (refuelling cycle) will gradually be replaced by the 15-month campaigns, and this is only feasible by means of higher-enriched assemblies.

The spent fuel pools hold fuel assemblies, which had already been operating, but were not delivered for some reason to the ISFS. These reasons include the following:

- they form a strategic reserve, that is, they are still suitable for operation. Currently, the Paks Nuclear Power Plant has 146 of such fuel assemblies.
- Failure of a kind (e.g: leakage), because of which they cannot yet to be transported to the ISFS. Until 01.01.2015 three fuel assemblies developed a leak at the Paks Nuclear Power Plant. Their storage needs to be arranged at a later time in accordance with Chapter 5.1.1.2.
- They have an excessive high residual thermal output for delivery to the ISFS, i.e. their rest time did not yet reach the periods below:
    - 36 months in case of 1.6%, 2.4% and 3.6% enrichment,
    - 42 months in case of 3.82% and 4.2% enrichment and
    - 46 months in case of 4.7% enrichment.

---

[3] Enrichment: the process by which the share of uranium isotope with 235 mass number, which is present in natural uranium is a very low proportion (0.7%), is increased. Most of the reactor types can work only with fuel assemblies containing enriched uranium. A widely accepted term in the industry is "an assembly enriched to a certain percentage".

The fuel assemblies returned to the Soviet Union and later to the Russian Federation can be divided into three groups:

- Between 1989-1998, under the Hungarian-Soviet intergovernmental agreement (see Annex 0 [1]) 2,331 pieces of spent fuel assemblies were returned, so that the secondary radioactive waste generated during their processing shall remain for final disposal in Russia.
- In 2003, 30 pieces of fuel assemblies were damaged during the cleaning of fuel assemblies in pit 1 of Unit 2. In 2006, the fuel parts of these 30 pieces of damaged part fuel assemblies were sealed into 44 capsules type T29 and 24 capsules type T28. In the summer of 2014 the 30 encapsulated damaged fuel assemblies were shipped back to the Russian Federation in 4 containers type TUK6.
- During its service life of the nuclear power plant so far five fresh fuel assemblies, without irradiation, were returned; three fuel assemblies were not used because of mechanical, geometric non-conformities, two additional fuel assemblies became redundant because of the transition to higher enrichment performed in the meantime.

From the management of burned out or fresh fuel delivered the Russian Federation as listed above, no radioactive waste requiring management will be returned to the territory of Hungary.

From its commissioning in 1997, the rate of transfer of spent fuel for interim storage in the ISFS has been as scheduled. A total of 8,077 pieces of fuel assemblies have been put into storage until 1 January 2015.

4.1.2 Estimating quantities of spent fuel to be generated in the Paks nuclear power plant in the future

Based on the official license the transition to 15-month campaigns is started from 2015. Fuel charges, which allow 15 months long campaigns will be provided for Unit 3 in 2015, for Unit 2 in 2016, for Unit 4 in 2017 and for Unit 1 in 2018. With respect to fuel consumption, the implication is that in addition to the use of existing fuel assemblies with 4.2% enrichment, it will also be necessary to use fuel assemblies with higher (4.7%) rate of enrichment.

The number of spent fuel assemblies generated during normal operation of the power plant can be well estimated. The transition to 15-month fuel cycle will result in the replacement of 102 pieces of fresh fuel assemblies during each refuelling, however, every five years, only four refuelling cycles will take place. Thus, per year and per unit an average of 81.6 pieces of spent fuel assemblies will be removed. In case of the 12-month refuelling cycles per year and unit 84 spent fuel assemblies will be removed. Compared to the current 12-month fuel cycle, it found that the number of long term fuel consumption and hence the resulting spent fuel will be reduced. According to the plans - taking into account scheduled introduction of the 15-month campaign – it is estimated that by the end of the operating life 6,510 additional pieces of fresh fuel assemblies will be used.

Looking at the disposal of spent fuel assemblies, arrangements shall be made for the future disposal of 1,396 fuel assemblies currently in service in the reactors, the 1,733 assemblies in the spent fuel pools and the 6,510 fuel assemblies to be used in the future, i.e. units, for a total of 9,639 pieces of spent fuel assemblies.

4.2 Spent fuel generated in the Budapest Research Reactor

At the start of its operation the Budapest Research Reactor (in 1959) used as fuel type EC-10, with 10% enrichment and after its first refurbishment it used VVR-M and VVR-M2 type fuel enriched to 36%. Pursuant to the Agreement (see Annex 2 [2]), promulgated in the Government Decree No. 204/2008. (19 August 2008) these spent fuels were transported in 2008 and 2013 to the manufacturer's home country, the Russian Federation, to which the Government of the United States provided partial support in accordance with the Government Decree No. 179/2008 (5 July 2008) (See Annex 2 [2a]). The amount and type of fuel assemblies transported are shown in Table 11.

Table 11: Type and the amount of spent fuel delivered from the Budapest Research Reactor to Russia

Date	Spent fuel type	Enrichment	Quantity (pcs)
2008	EC-10	10%	82
	VVR-M	36%	1,188
	VVR-M2	36%	216
2013	VVR-M2	36%	515

The unused 36% enriched fuel assemblies of the Budapest Research Reactor were airlifted back to Russia in 2009. That included the delivery of 157 pieces of fuel assemblies (20 pieces of VVR-M and 137 pieces of VVR-M2).

The fuel was delivered subject to such conditions that any secondary waste from its processing of cannot be returned to Hungary. The Budapest Research Reactor is currently operating with fuel type VVR-M2 of 19.75%. The average burnout rate of the VVR-M2 fuel of 19.75% enrichment is 60%, the average heavy metal content of the spent fuel assemblies is 220 g (the residual ^{235}U contents is 18-25 g).

The core of the Budapest Research Reactor is constructed with triple and single fuel assemblies, which may take up 190 positions in the core. The fuel assemblies can be divided into five groups, consisting of 38 single assemblies based on the, time spent in the zone. In the course of refuelling, one group is replaced and the rest are reshuffled to the required positions to ensure the flux needed for an adequate burnout, subject to the user's requirements and the regulatory limits.

Use of the fuel is a function of the operating time. In the case of the former intensive operation an average of 70 pieces of fuel assemblies were exchanged each year. At the current level of use this is 38 fuel assemblies per year and in case of the planned 12-cycle operation this can amount to 45 fuel assemblies / year.

The Budapest Research Reactor currently has 462 nuclear fuel assemblies, of which 76 are spent, the reactor holds 190 and 196 wait for use. Until the shutdown date specified as a reference (in 2023) a total of 642 spent fuel assemblies are expected to be generated, the heavy metal mass of which is 141.24 kg.

4.3 The spent fuel generated in the Training Reactor

The Training Reactor of the BME University has been operating since 1971. Training Reactor is of the light water moderation, pool-type reactor, the current allowed maximum thermal output is 100 kW. Active zone has 24 pieces of EK-10 type fuel assemblies of 10% enrichment, with a total mass of 30 kg of uranium.

The fuel loaded into the core before commissioning into service is still in place, i.e. no refuelling has been carried out in the reactor. During the 1980 performance increase included the addition of a fresh fuel assembly to the charge in the core. The operation of the Training Reactor will continue with this fuel into the future. Accordingly, prior to the final shutdown the generation of spent fuel is not expected.

At the time of the final shutdown, accordingly, 24 EK-10 spent fuel assemblies need to be reckoned with. Their burnout levels will be very low (1% or less ^{235}U consumption is expected).

In the 1980s, the BME Nuclear Technology Institute's predecessor - in order to accumulate reserve fuel - bought 28 EK-10 fuel assemblies from the then Czechoslovakia, which were used in 1970 - 1975 in the critical system of the SKODA Works (with a maximum power of 100 watts). These assemblies are currently recorded as irradiated but not as spent fuel.

At the time of final closing – in the reference case (see Chapter 3.2.1) – in 2027, the slightly irradiated fuel stored in the building of the Training Reactor (28 fuel assemblies) will also be counted as burnt out, as they spent time during their service life in a critical system, allowing chain reaction. The burnout rate of these fuel assemblies is extremely small, given their low surface dosage intensity they can be handled manually.

In addition to the 24 pieces of fuel assemblies operated in the reactor and 28 pieces of irradiated fuel assemblies, the Training Reactor has also fresh fuel equivalent to four fuel assemblies.

4.4 Spent fuel generated in the new nuclear power plant units

The core of the new reactors will consist of 163 fuel assemblies. Each assembly will consist of 312 fuel rods, 18 control rod guide tubes and one detector guide tube. The enrichment of the rods range from 4.37 to 4.93%. Depending on their profiling, the fuel assemblies contain 6-27 pieces with burnable poison. These rods contain 5-8% of gadolinium. There are 121 control rod assemblies above the core.

The new nuclear power plant units switch to 18-month refuelling cycles after the initial campaigns of 12 months. In the latter case, each campaign 72-73 pieces of burnt up fuel assemblies are removed from a reactor. This means 144-146 assemblies regarding the two units in every 18 months. The fuel assemblies will have the parameters as stated in Table **Hiba! A hivatkozási forrás nem található.**.

Table 12: The anticipated features of the fuel assemblies used in the new reactors (TVS-2006)

Parameters characterizing the assembly	Value
Total mass of assembly (kg)	750
Mass of UO_2 in the assembly (kg)	534
Total length of an assembly (mm)	4,570
Active length of an assembly (mm)	3,730
The maximum distance across flats (mm)	235
The number of fuel rods in the assembly	312
Average enrichment (^{235}U% m / m)	4.85%
Average burn-up (GWd / tU)	55

The burn-up rate of the assemblies upon unloading will be covered by curve of value of 55 MW day 55 / kgU. Of the initial uranium mass of these fuel assemblies typically 1-2% is provided by plutonium, 0.1% by the secondary actinides, 5% by the fission products and 93% by the residual uranium. On this basis one fuel assembly will contain approximately 8.9 kg of plutonium, 0.5 kg of secondary actinides, 438 kg of uranium and approximately 23.6 kg other fission products. It is important to note that the amounts shown above are indicative numbers, preliminary estimates. Exact amounts can be given only at the moment of their removal from the core, because their value is highly influenced by the regime of operating. The specific mass of plutonium and secondary actinides can be re-estimated for the first time on the basis of the Preliminary Safety Analysis Report. By the end of the 60 year life-cycle of the two units 6,100 burnt-up fuel assemblies will be produced.

4.5 Spent fuel inventory

The vast majority of spent fuel is generated in Hungary in nuclear-based electricity production. Small volumes are contributed by the burnt-up fuels from the Budapest Research Reactor and the Training Reactor. The inventory of spent fuel is summarized in Table 3, which also contains the heavy metal masses for better comparability.

Table 3: The aggregate inventory of spent fuel inventory In Hungary

Spent fuel source	**Total volume generated**	
	Assembly [pcs]	**Heavy metal mass [kg]**
Operation of Paks units 1-4	17,716	2,125,920
Operation of Paks units 5-6	6,100	2,874,000
TOTAL:		**4,999,920**
Operation of Training Reactor	56	69
Operation of Research Reactor	1,092	240
TOTAL:		**309**

The data in the table show that considering the 50-year service life of the four units of the Paks Nuclear Power Plant ~ t_{HM} 2,130, and taking into account the 60-year service life of the new NPP units as well, preparations shall be made for the production of nearly 5,000 t_{HM} burnt-up fuel.

5 Management of spent fuel

The amounts and management strategy of spent fuels generated in the energy reactors and in the Training and Research Reactors, respectively, significantly differ from each other. Therefore, in this main chapter first the management of spent fuel generated in the energy reactors is discussed - the temporary storage (Chapter 5.1) and the closing stage of the nuclear fuel cycle (5.2 Chapter) - will be presented, followed by a description of the management of spent fuel produced in the Training and Research Reactors (Chapter 5.3).

5.1 The interim storage of spent nuclear fuel from energy reactors

Interim storage - even though it cannot be considered a final solution – is an essential element of the line of technological steps applied for the treatment of spent fuel. One the one hand, decades of exploration and construction processes are necessary for the establishment of a deep geological repository in Hungary which is inevitably necessary for the disposal of burnt-up fuel, or high-level and long-life waste resulting from reprocessing activities, which would mean the final solution to the management of these materials. On the other hand, especially in power reactors, a certain degree of "cooling" of the spent fuel (reduction of thermal output due to radioactive decay) is required for the following technological steps - whether it is final disposal after delivery or reprocessing.

5.1.1 Interim storage of spent fuel of Paks Nuclear Power Plant

5.1.1.1 Establishment of the Interim Spent Fuel Storage Facility

Upon the approval of the engineering plan of the Paks NPP in the late 1970's the prevailing concept of the late 1970s was that the spent fuel assemblies stored in the nuclear power plant's spent fuel pools, after three years of relaxation, would be returned to the Soviet Union free of charge for reprocessing so that all the end products of processing will remain in the Soviet Union. After commissioning the first unit of the nuclear power plant the Soviet Union several times changed the terms and conditions of return. Complying with the altered conditions, Paks Nuclear Power Plant returned a total of 2,331 spent fuel assemblies to the Soviet Union (and later to the Russian Federation) between 1989 and 1998.

Therefore, in the initial period of operation of the nuclear power plant only the spent fuel pools located next to the reactors provided a certain amount of storage, and no interim storage facility with high capacity and for a longer time horizon (a few decades) has been established in Hungary.

In the first years of return it was suggested, due to the political and economic changes occurring in Europe and in the Soviet Union suggested that the practice of returning the spent fuel cannot continue for long, despite satisfying the increasingly stringent conditions. It was decided that in addition to retaining the possibility of returning the spent fuel to Russia, real alternative shall be prepared in Hungary. The professionals of the nuclear power plant, after a thorough, multi-criteria type selection process, elected the type of modular chamber based, dry storage (Modular Vault Dry Storage: MVDS) for the establishment of ISFS, which would provide an interim storage facility for burnt-up fuel.

Having obtained the required licenses, the ISFS was commissioned into service in 1997 and its loading with spent fuel was also started. Thereafter, the ongoing operation of the ISFS ran in parallel to the expansion and this activity it is still ongoing.

The ISFS is a single floor building in which the fuel assemblies are placed one by one in vertical, thick-walled, hermetically sealed steel tubes. The tubes stand in vaults surrounded by concrete walls. The concrete enclosure surrounding the storage tubes provide adequate shielding against radiation.

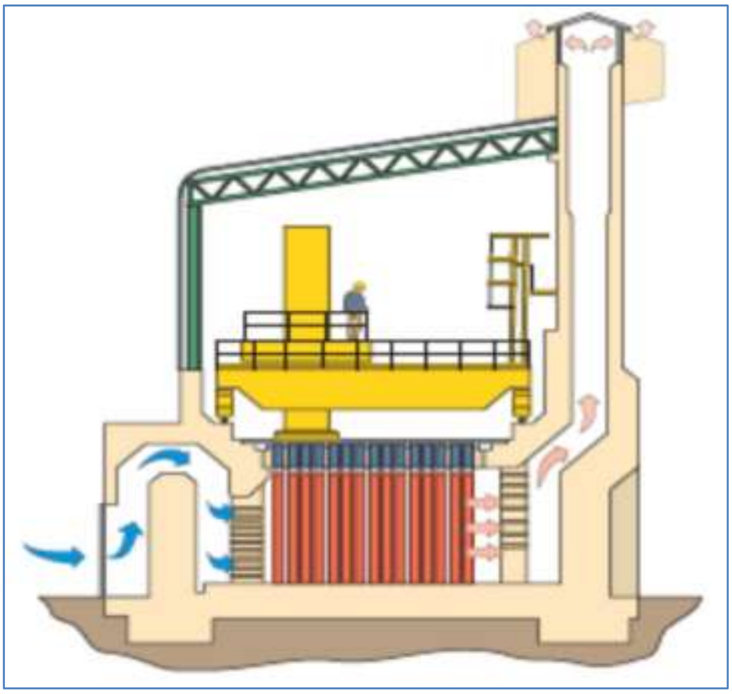


Figure 6: The passive cooling system of the ISFS

The storage is done under dry conditions, the residual heat produced is removed by the cooling system based on a natural draft effect (see Figure 6). So cooling will not be terminated as a result of electrical or mechanical failure. The cooling air flows among the storage tubes, so it cannot contact directly the fuel assemblies. The storage tubes have an inert (nitrogen) gas environment, thus the corrosion of the cover of the rods is negligible.

In the original design of the facility (vaults 1-16) a vault included 450 storage positions (storage tubes). From the vault No. 17 – with a denser storage tube layout – a vault could accommodate 527 positions. Thus, the current configuration of the facility with 20 storage vaults provides an opportunity for the storage of a total of 9,308 spent fuel assemblies.

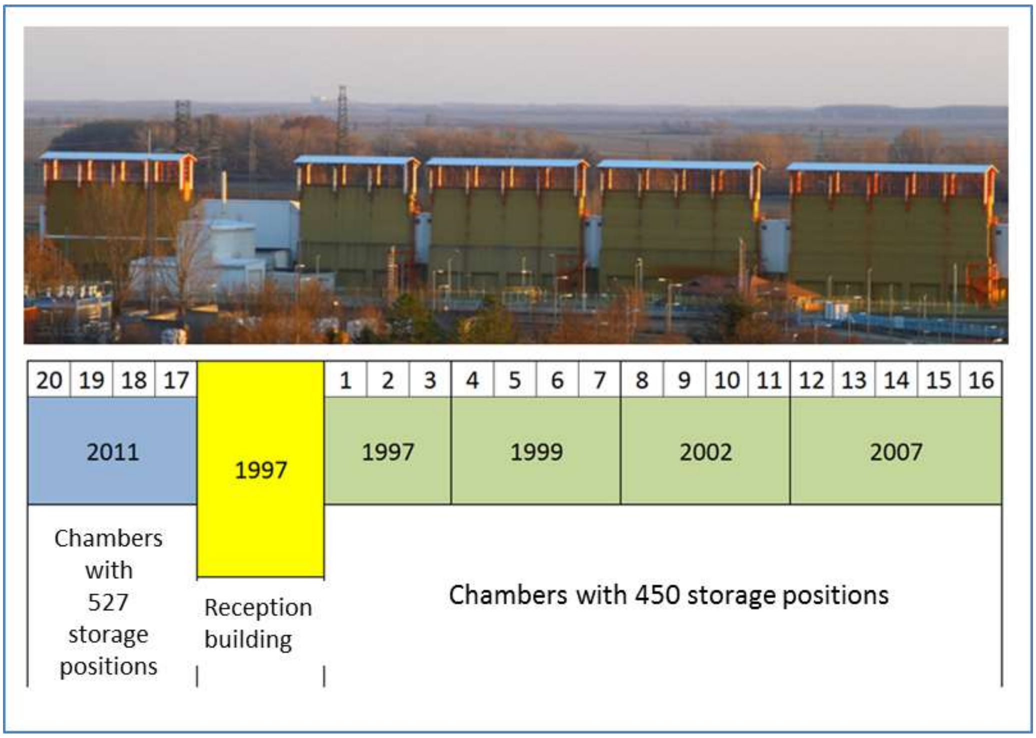


Figure 7: The current layout of the ISFS

The construction and commissioning of the ISFS can be implemented in modular stages, according to the pace of spent fuel delivery. The configuration built so far, the modules of the various construction phases, included three, four or five vaults, as shown in Figure 7.

5.1.1.2 The operation of the Interim Spent Fuel Storage Facility

The spent fuel assemblies are transported from the spent fuel pools of the nuclear power plant after cooling for several years (5-6 years, on the average) to the ISFS under wet conditions in special C-30 containers, which can accommodate 30 spent fuel assemblies at the same time. The assemblies - after removal from the C-30 container filled with water – are dried one by one with hot air. After drying, the fuel assembly is transferred from the drying tube into the refuelling machine, which carries the assembly to the appropriate storage tube and inserts it. The refuelling machine operating within a closed space above the storage tubes, which is called loading hall. Before sealing the tube is evacuated and filled with nitrogen, providing an inert gas environment for the interim storage of the spent fuel.

On 01.01.2015 a total of 8,077 spent fuel assemblies were stored in the facility. The annual breakdown of the spent fuel supply is shown in Figure Figure.

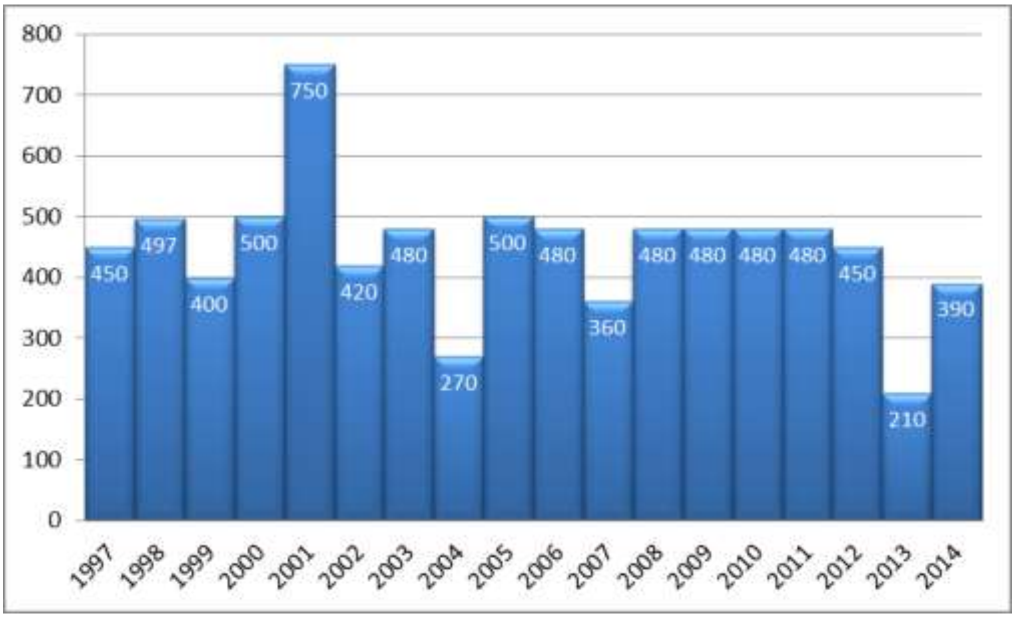


Figure 6: Spent fuel amounts delivered so far into the ISFS in an annual breakdown (pieces)

During the operation of the ISFS very small amounts (an average of 4-5 m^3) of low and intermediate level waste are generated, which mainly comprises of filters, cleaning equipment, decontamination equipment and protective clothing. These wastes are transferred, after classification according to the specified program, to the waste treatment system of the nuclear power plant, so they are later registered as part of the waste generated in the nuclear power plant.

For the nuclear facilities the legislation in force requires with a frequency of 10 years the implementation of a Periodic Safety Review. The operation license of the facilities is aligned to this period, which in the case of the ISFS is valid until 30 November 2018. The Periodic Safety Review for the ISFS will have to be carried out so that the documentation and periodic safety report showing its results shall be submitted to the nuclear oversight body for approval until 30 November 2017.

A technical concept plan was completed about the possible ways to take spent fuel assemblies into storage in the ISFS if they have detectable levels of leaks, i.e. requiring special storage. Along this concept detailed technical designs, underpinning calculations will have to be completed, and it will be required to start the necessary modification of licenses based on them. The implementation of the necessary technical modifications in the facility will be possible thereafter.

5.1.1.3 Milestones for the further construction of ISFS

The further expansion of the ISFS, in accordance with the practice described above, is planned in modules in line with the delivery schedule of the spent fuel produced. The construction of the new module containing vaults 21-24 is currently underway to be completed in 2017 according to the plans.

In parallel with the construction activity a work has begun that aims at the further increase of the capacity of the ISFS. The technical plans and their underlying security calculations were completed, proving the feasibility of increasing the density of storage tubes, which would allow the storage of up to 703 spent fuel assemblies starting from vault No. 25. Based on the documentation prepared the necessary licensing procedures may be carried out by the end of 2016, to enable the expansion of the ISFS under the new concept.

The interim storage of spent fuel from the Paks nuclear power plant is planned in a more conservative way, with technical solutions providing 527 storage positions in each vault, in accordance with the current permits. The concept of the time schedule and cost estimates provides the basis of payment by the nuclear power plant to the Fund. Table 14 shows the building schedule of the individual modules, taking into account the spent fuel delivery rate from the Paks NPP.

Table 14: The timing of modular expansion of the ISFS

Part of the facility	Construction completed in	Total number of storage positions (pcs)
Vaults 21-24	2017	11,416
Vaults 25-28	2024	13,524
Vaults 29-32	2029	15,632
Vaults 33-36	2035	17,740

The amount of spent nuclear fuel generated during the entire 50 years of life, - which includes also the 20 year service life extension, - in the 4 units of the Paks NPP to be stored in Hungary comes to 17,716 fuel assemblies, which can be held, in accordance with the currently approved storage concept, in the facility configured to contain 36 vaults. If the increase of the storage capacity of the vaults to 703 is approved starting from vault No. 25, with the construction of 33 vaults the same amount of spent fuel can be held in interim storage. The denser storage pipe layout, with the same security standards, may lead to a more cost effective interim storage method.

In the event that a decision is made concerning the closing phase of the nuclear fuel cycle (see Chapter 5.2.1), which provides for the reprocessing of the spent fuel from the Paks NPP prior to completing the full deployment of the storage facility, then, due to the modular design, it is still possible that the last module or modules are not built.

5.1.2 Options for the interim storage of spent fuel of the new units

The two new nuclear power plant units are expected to be commissioned into commercial service in 2025 and 2026, respectively. After the start of the first unit, the first charge of spent fuel assemblies shall be lifted from the reactor after the expiry of the first campaign lasting 12 months and transferred to the spent fuel pool. The spent fuel assemblies are cooled for 5-10 years in the spent fuel pool. The relaxation in the spent fuel pool of the fuel assemblies removed first will be completed around 2031-2036, after which arrangements shall be made for their depositing in the interim storage facility.

The interim storage of spent fuel assemblies shall also be provided in case of the new units. On the one hand, because of deep geological storage of providing a final solution will be available in Hungary nearly 30 years after the end of relaxation of the first spent fuel assemblies. On the other hand, because of the rate of heat generation due to the decay of radioactive isotopes present in the spent fuel, the interim storage of the fuel will be necessary for several decades necessary for compliance with the technical limitations concerning heat development for the final disposal. The necessary term of interim storage and the limit of heat development will have to be clarified taking into account the characteristics of spent fuel and disposal system.

If during operation of the new units the application of reprocessed fuel takes place (for the analysis covering the closing stages of the nuclear fuel cycle, see Chapter 5.2) then the possibility for the interim storage of reprocessed spent fuel (e.g.: burnt-up MOX or REMIX) must be provided in the interim storage.

Interim storage of spent fuel can be realized in domestic and foreign storage facilities authorized to receive spent fuel. Conditions for interim storage in Hungary can be given, the site of the interim storage location is shown in the design drawings of the new units. Under the authorisation of the new storage facility, it will be necessary to conduct an environmental impact assessment procedure as well as a nuclear safety authorisation procedure.It is important that the environmental impact assessment explores the environmental impacts of the site together with the establishment of the new interim storage facility. In the case of storage in Hungary the costs of building and operation of the storage facility will have to be taken into account of costs and the duration of temporary storage will also be of key importance.

In case of interim storage abroad the relevant conditions must be agreed upon during the negotiations between the parties. Interim storage is also possible in Russia for within the framework of the Hungarian-Russian Intergovernmental Agreement promulgated by Act II of 2014. The price proposed in the scheme compared to the cost of storage in this country shall be considered when deciding on the option better serving the interests of the Hungarian party.

The choice between the options should be made to ensure availability by the time the first charge removed from the relaxing pool, whichever of the options is elected. That date is determined by obtaining the necessary licences for domestic interim storage and the construction, so it is expected to be due at the time of starting up the new units.

5.2 The closing stage of the nuclear fuel cycle for energetic reactors

Basically there are today two concepts for the closing stages of the nuclear fuel cycle in the international practice: direct disposal of the spent fuel (open fuel cycle), and some degree of reprocessing, respectively.

In an open fuel cycle, the spent fuel, after the necessary rest time, without any further processing, is directly placed in special airtight containers for permanent depositing in a deep geological repository designed for this purpose.

The most important advantage of an open fuel cycle is that it does not require complex technological operations, however, a non-negligible amount of fissile material in the spent fuel remains unutilized.

The spent fuel assemblies placed without reprocessing, in this case, shall be classified as high-level radioactive waste and have considerable heat generation compared to the low and intermediate level radioactive wastes.

The partial reprocessing, currently conducted on an industrial scale, the uranium and plutonium isotopes suitable for additional generation of power, are separated, and high level and long life waste remains as processing by-product, however, in a significantly smaller volume than the spent nuclear fuel before reprocessing. The waste must be permanently deposited, like the spent fuel, in deep geological repository, while design of the waste package, its isotope composition, forms of waste and rate of heat production are significantly different from those of the spent fuel, so the size of the deep geological storage built for holding reprocessing waste can be significantly smaller.

Fuel can be produced again from plutonium and uranium separated during processing, which can be partially or completely made by the enrichment of the so-called reprocessed uranium, the ERU (Enriched Uranium Reprocess) and the MOX fuel also containing plutonium, they are suitable for reuse in energetic reactors suitable for the purpose.

Reprocessing can also take place without reprocessing the uranium and plutonium, but then agreement shall be reached with the countries about the sale of fissile materials, the mode and conditions of their use for other purposes or of their storage.

Reprocessing of spent fuel is now a well-established practice implemented at an industrial level, however, it is a very complex technology, and therefore only a few countries have it. Reprocessing plant - based on economic and technical considerations - should be established only in international cooperation or a country, which has a significant nuclear industry, so if in Hungary the reprocessing of spent fuel becomes necessary, it must be carried out abroad.

In the reprocessing procedure currently used, the fissile material in the fuel assemblies resulting from the first processing, after they burn out – because of the difficulties of reactor physics and engineering for reuse in the reactor – are not recovered for a second time, i.e., the fuel recycling cannot be complete in a nuclear power plant system purely incorporating water cooled reactors. Therefore, this fuel cycle is actually considered to be only partially closed.

The development of a technology is under preparation, which is based on the production of fuel known as REMIX (REgenerated MIXture of uranium and plutonium oxides) from fissionable uranium and plutonium isotopes that are separated during the reprocessing as well as from smaller amounts of higher enriched uranium. This fuel has the benefits that according to preliminary plans, the core can be fully charged with REMIX fuel and may be suitable for multiple reuse as well.

The development of advanced processing technology of spent fuel is in the research phase, which is expected to provide multiple recycling of, in addition to uranium and plutonium, the secondary actinides (neptunium, americium, Curium). This requires that in addition to uranium and plutonium, the separation of other (secondary) actinides also takes place. Closing the fuel cycle may be accomplished through the total recycling of uranium, plutonium and other actinides. This objective may be achieved through intensive research also going on at this stage, on a commercial scale in the second half of the 21st century, probably through the use of fourth generation reactors.

5.2.1 The closing phase of the nuclear fuel cycle of operating power reactors

5.2.1.1 Theoretical possibilities for the closing stages of the nuclear fuel cycle

The Hungarian strategy for the management of spent fuel being produced in the currently operating four units of the Paks Nuclear Power Plant may consider the following key possibilities:

A. Interim storage and subsequent final disposal of spent fuel (direct disposal).

B. Spent fuel reprocessed abroad and final disposal of the resulting radioactive waste in deep geological repository being built in Hungary (reprocessing).

C. Spent fuel processing and extraction of secondary actinides abroad, and final disposal of the resulting radioactive waste in deep geological repository built in Hungary (advanced reprocessing).

The main features of the three alternatives are presented below.

A. <u>Direct placement of the spent fuel.</u>

This alternative is the current design base of the program section for the management of high-level long-life waste to be presented in Chapter 6.3 which is used at this time as the so-called reference scenario of cost estimates and financing system to be presented in Chapter 11 and was also used in the earlier years. If this version is selected for closing the nuclear fuel cycle, then after the storage in the interim storage facility with extended operating time, the spent fuel will be directly placed in the deep geological repository, planned to be operating from 2064.

Currently it does not seem realistically feasible that the direct placement of the spent fuel takes place regionally or in a foreign country, therefore, only a deep geological storage repository planned for Hungary comes into play. The establishment of a regional repository is not hindered by technical reasons, but there are problems related to political decision-making and in connection with the social acceptance of receiving radioactive waste from other countries for final disposal arise, which seem to be difficult to solve at this time.

B. *Spent fuel reprocessing*

Spent fuel can be reprocessed within a few years after resting in the nuclear power station (i.e. even without temporary storage). Currently the fuel stored in the operating interim storage facility, having already rested for several years, is suitable for chemical reprocessing without any need for additional interventions.

Today, the so-called PUREX (Plutonium and Uranium Recovery by EXtraction) process is used on an industrial scale, in course of which the spent fuel assemblies are cut up, separating the metal structural materials, and the spent fuel is dissolved in nitric acid. Plutonium and uranium are extracted from the solution, everything else will be classified as radioactive waste (including other actinides and fission products), which will be vitrified. The further course taken by the material streams generated during the reprocessing is worth addressing separately.

From the separated uranium and plutonium, as previously described, ERU and MOX (and in the future REMIX) fuel can be obtained by means of three possible ways. On the one hand, the reactors of the Paks Nuclear Power Plant cannot be operated with the MOX fuel obtained from spent fuel reprocessing at this time – lacking licenses and certain technical solutions – and the return of investments in the necessary modifications is not expected during the remaining 20 years of life, therefore, the re-use of separated uranium and plutonium is unlikely in the existing four VVER-440 reactors of the Paks Nuclear Power Plant. On the other hand, the re-use of uranium and plutonium in the new nuclear power plant units may be suggested, which is discussed in Chapter 5.2.1.3 in more detail. A third option is to establish a contractual arrangement whereby the separated fissile materials are sold, so their recycling may take place abroad.

If all spent fuel was reprocessed from the currently operating four Paks units until their final shutdown, then about 500 tons of vitrified high-level radioactive waste would arise. This could be deposited in the same type, although a significantly smaller, of a deep geological repository, than the one required for the spent nuclear fuel. It explains why, already before the final decision on the fuel cycle closing stages, it is possible to carry out the designation of the deep geological repository site for the storage of high level radioactive waste, its analysis, and later the preparations for establishment, in accordance with Chapter 6.3.

The reprocessing of fuel used in the reactors type VVER-440 of the Paks Nuclear Power Plant, in accordance with the currently available information, could be performed in two plants; one of which is the French La Hague plant and the other is the Russian Mayak plant. In addition to the security and business aspects, the site selection process should also examine the planned service life of the individual plants and also how the operator plans their development. Given the fact, that a relatively limited demand exists for a service processing the fuel of the VVER - 440 reactors, preparations should also be made for the case that reprocessing capacity may not be available until the end of the service life or the units.

An important consideration can also be the length of the period undertaken by the individual plants for the interim storage of vitrified high-level waste after reprocessing. If, after the reprocessing it becomes necessary to return the radioactive waste in a short time, then preference shall be given to longer domestic interim storage and delayed outsourced reprocessing of the spent fuel, or arrangements shall be made for the interim storage of vitrified high-level waste in this country by establishing a new intermediate storage facility (or converting the existing ISFS to accommodate the vitrified high level waste).

C. *Further improved reprocessing of spent fuel*

This alternative only differs from the option presented in Section B that during the reprocessing a more advanced technology is applied. This technology exists today only on a laboratory scale – but it allows the extraction from the spent fuel of the other, so-called secondary actinides, in addition to uranium and plutonium, either separately or together with the plutonium (the latter would significantly reduce the risk of proliferation of reprocessing). The remaining high level waste will be vitrifying in the same way as in the previous case, however, this waste would have a significantly lower activity and radiotoxicity.

This case is very beneficial in many ways, but it may only be a real solution, if prior to the decision, branch points set by this program Hungary is given the possibility of using this technology as a service. In this respect, a reliable estimate cannot be made now, so this strategic opportunity cannot be treated as a reality, but it will only be taken into account in specifying the relevant research and development tasks in Chapter 8.2.

5.2.1.2 Strategic scenarios for closing the nuclear fuel cycle of the operating units

Therefore, the two basic and currently programmable way of final management of spent fuel is direct final disposal (Scenario A) and reprocessing (Scenario B). The strategic version described in Scenario C is uncertain to such an extent that it cannot be recorded for the purposes of the current national program. Given that due to technical, economic and other aspects, the processing of the total fuel quantity may not happen, the program must deal with a "mixed" scenario assembled from the elements versions A and B.

On the basis of the strategic considerations described in the preceding paragraphs and subject to boundary conditions specified by other elements of the national program, the scenarios for the closing phase of the nuclear fuel cycle of the currently operating reactors are conceivable in a logical system shown in Figure 9.

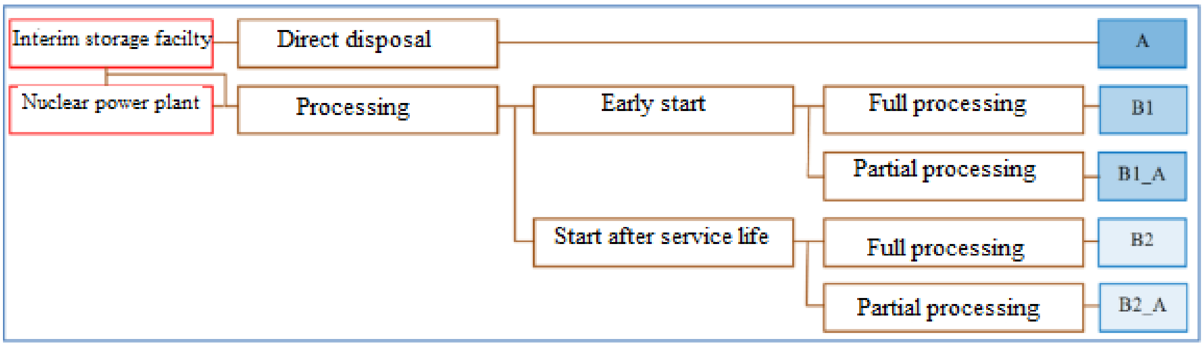


Figure 7: The scenarios for closing the nuclear fuel cycle of operating units

A. *The interim storage of spent fuel and its subsequent final disposal*

In this case, the tasks in the schedule not including bifurcations and decision-making nodes must be implemented in connection with the interim storage of spent fuel in the ISFS and, thereafter, of its final disposal in the national deep geological repository. This is considered a reference case for the Paks Nuclear Power Plant, and it is the basis of calculation of payment to the Fund.

B1. *Early reprocessing of spent fuel abroad, final disposal of vitrified radioactive waste resulting from reprocessing, after interim storage, in Hungary.*

The early start of reprocessing, the one hand, allows the halting of the ongoing expansion the ISFS (after the completion of the modules being built at that specific moment in time) within a short period of time after the decision. The delivery for reprocessing will release the previously commissioned and loaded modules of the ISFS, so during the remaining service life those modules can receive the spent fuel. The earlier a decision is reached on the early reprocessing, the construction of more modules becomes unnecessary.

However, an early start of reprocessing related to the start of operation of the deep geological repository, leads to a situation in which a significant portion of the processed, vitrified high-level waste will have to be put in interim storage for a relatively long time either on the site of reprocessing or in Hungary. An interim storage facility suitable for holding the vitrified high-level waste is much more compact and simpler than those that are used for the interim storage of spent fuel.

The scenario may include two sub-variants depending on whether total volume of all spent fuel of the Paks Nuclear Power Plant is processed or the degree of processing will only be partial (sub-case marked _A). In case of partial processing, the unprocessed fuel, after encapsulation, shall be directly deposited in the chambers of the deep geological repository designed for the purpose. Technically it does not seem appropriate to build chambers of different technical solutions in a deep geological repository for waste packages of different characteristics. Partial processing will probably not be justified from marketing and technical aspects.

Until the decision node for possible reprocessing, the feasibility of processing option must be assessed with the help of a detailed comparative safety, technical and economic analysis, which also considers the plans for the closing stages of the fuel cycle of the new units. It should be investigated that whether the processing of the resulting total amount of spent fuel can be ensured. It is necessary to determine the extent of the expected cost reduction in interim storage and in the building of the deep geological repository, as well as the savings derived from the use of uranium and plutonium recovered by reprocessing. It is necessary to determine the expected costs of interim storage of the reprocessing of waste - prior to its final disposal. If reprocessing proves to be more economical overall, a decision must be made based on the availability of reprocessing possibilities as to the time to begin reprocessing.

B2. Reprocessing of spent fuel abroad, after the decommissioning of the units, final disposal in Hungary of the vitrified high level waste produced in the course of reprocessing.

The late start of reprocessing requires the constant expansion of the ISFS with new modules. However, reprocessing adjusted to the time of commissioning the deep geological repository, in turn, may result in the option of transporting the processed, vitrified high level radioactive waste from the reprocessing site directly to the final repository, without any longer interim storage, although justifying this will require a detailed thermal engineering analysis - , taking into account the characteristics of the host bedrock and placement system.

This scenario may also contain two sub-variants, depending on whether total volume of all spent fuel of the Paks Nuclear Power Plant is processed or the degree of processing will only be partial (sub-case marked “A”). In case of partial processing, the unprocessed fuel, after encapsulation, shall be directly deposited in the chambers of the deep geological repository designed for the purpose.

At the latest until 2042 the feasibility of processing options must be assessed by means of a detailed, comparative, safety, technical and economic analysis, taking into account the fuel cycles of the new units as well. It should be investigated to ensure that processing whether the resulting total fuel volume. It is necessary to determine the extent of the expected cost reduction in interim storage and in the building of the deep geological repository, as well as the savings derived from the use of uranium and plutonium recovered by reprocessing. It is necessary to determine the expected costs of interim storage of the reprocessing of waste, prior to its final disposal.

5.2.1.3 Possibilities of re-using the fissile material recovered during the reprocessing

Table 15 shows the estimated amount of plutonium and uranium, which can be extracted and recovered from the processing of spent fuel generated in the currently operating four reactors until the end of the planned 50-year service life at the Paks Nuclear Power Plant.

Table 15. Usable plutonium and uranium accumulated in the spent fuel

^{238} Pu mass (t)	0.74		
^{239} Pu mass (t)	12.49	^{234} U mass (t)	0.18
^{240} Pu mass (t)	5.02	^{235} U mass (t)	14.40
^{241} Pu mass (t)	1.11	^{236} U mass (t)	15,98
^{242} Pu mass (t)	1.86	^{238} U mass (t)	2,062.37
Total Pu mass (t)	**21.22**	**Total U mass (t)**	**2,092.93**

The MOX fuel utilization in Hungary is only a potential scheme, in which the MOX fuel produced from the spent fuel of the current reactors would be loaded into the new reactors coming on stream later. In accordance with the plans for the new nuclear power plant units, the earliest opportunity for this would be in the 2040's. It should also be borne in mind that that at point in time the more advanced fuel also of the mixed oxide type (e.g.: REMIX) currently in a pilot phase, but allowing multiple reprocessing may become available.

For all these reasons, if the reprocessing of the fuel would take place prior to the shutdown of the reactors, then in the absence of own use, preparations must be made by all means for the long-term storage and / or sale of plutonium originating from processing.

Domestic storage of the plutonium does not seem feasible for proliferation and other aspects, and is not currently considered to be a directly marketable product. Therefore, its storage shall be arranged in the country which performs reprocessing, possibly at a considerable cost. In the case of reprocessing in Russia, it is possible to utilize the plutonium in fast reactors, this may reduce the storage costs. However, the relevant commercial details remain to be clarified.

The ^{235}U content of spent fuel, in principle, allows the production of reprocessed uranium dioxide fuel (ERU) as well. After the reprocessing uranium will not only contain natural isotopes $^{(234}$ U, ^{235} U and ^{238} U), but also some isotopes that were produced during the irradiation $^{(232}$ U, ^{233} U, ^{236} U and ^{237} U). For uranium reprocessing the ^{234} U and ^{236} U isotopes are particularly important, which reduce the uranium usability arising from reprocessing due to the large absorption cross-section, as in such cases the fuel must be manufactured with higher ^{235}U contents than those originating from natural sources. Given that in Hungary the each of the reactors operating or planned for the future came close to 5% enrichment, which is currently the permissible limit for the energy reactors, therefore the use of such ERU fuels requires further work to solve additional tasks.

The possibilities of utilization of uranium and plutonium resulting from reprocessing apparently require additional considerations. Moreover, it is likely to incur significant storage costs prior to the recovery. The world market prices for raw uranium and enrichment services are currently relatively low. In turn, the production unit cost of the MOX fuel is higher. All these result in the processing option being economically attractive at this time, opposed to direct placement, not by the fuel recycling possibilities, but by the eventual cost reduction in the development of a deep geological repository. It is important to note that cost savings in the establishment in the deep geological repository will actually be realized if there will be no need to deposit there spent fuel (spent MOX fuel in particular) for final disposal, but exclusively high-level and long-life waste from reprocessing. This may require the harmonization of the cycle closing options of the old and the new Paks units.

5.2.2 The impact of the new nuclear power plant units on the closing stages of the nuclear fuel cycle

With respect to the new nuclear power plant units the same strategies can be considered in terms of the closing stages of the nuclear fuel cycle, that were presented for the Paks Nuclear Power Plant in Chapter 5.2.1.1.

It is a possible option that the spent fuel - after interim storage (see Chapter 5.1.2) – is directly deposited in this country. Reprocessing of spent fuel assemblies abroad may be suggested, and arrangements shall be made for the temporary storage and final disposal of the resulting by-product, which is a secondary high-level radioactive waste. The delivery of spent fuel assemblies for reprocessing may take place several years after having been stored in spent fuel pools, or even after decades of interim storage. Recycling options for fissile materials separated during the reprocessing were discussed in Chapter 5.2.1.3. The possibility of an enhanced reprocessing (separation and recycling of secondary actinides, in addition to uranium and plutonium) cannot be realistically taken into consideration so far even for the new units either, but it should be noted that over a longer time horizon of their operation, there will be a greater the likelihood that this technology becomes a real, industrially applicable practice also available to Hungary.

The industry projections indicate that the use of reprocessed fuel can play an important role in the sustainable operation of the nuclear power plants. This may entail that the new units will have to be licensed later, during their service life - and inevitably transformed, too – for operation with this type of fuel. If a decision is taken in this direction, the use of fuel reprocessed from the spent fuel generated in the current four units of the Paks Nuclear Power Plant may also arise in the new units as discussed in Chapter 5.2.1.3.

5.2.3 Decision-making points related to the management of spent fuel

Not all of the information is currently available for making choices between possible strategies for the closing phase of nuclear fuel cycle in the power reactors. In the future, however, decision-making points will be reached where choice will have to be taken among the options. With respect to closing the nuclear fuel cycle, the decisions must be made taking into account the total amount of spent fuel generated during the operation of all the six units, using an integrated approach. The following key decision points can be identified in relation to the energy reactors.

The first decision point arises with respect to the method interim storage of the spent fuel of the new units. The decision have to be taken before the end of the cooling time of the first charge, early enough that the licensing and construction of the interim storage facility can be implemented safely. This date is expected to coincide with the date of launching the new units. Choice must be taken between two options: i.e. temporary storage at home and temporary storage abroad (see Chapter 5.1.2). So any which of the options is chosen, there is sufficient time for its implementation.

Until the beginning of the 2040s at the latest, the feasibility of the processing option must be evaluated with a detailed comparative safety, technical and economic analysis regarding the fuel cycle of the 6 blocks, taking account of environmental and social considerations (second decision point). If the decision is made possibly later, it may already be possible to take into account the reusability of the fissile material, with the details described with the third decision-making point.

The third decision point comes around the mid-2040's. Depending on the economic environment change should be made to the reprocessing of spent fuel, and also to the use of fuel reprocessing, or continue the use of conventional uranium dioxide fuel. The time of decision-making is primarily decided by the duration of licensing the operation with reprocessed fuel. This decision can also be taken later, but at the latest when designing deep geological repository, in the early 2050's. The design of the deep geological repository (design basis of the repository) depends on the quantity and quality of waste generated in the course of the strategy to be followed. The transition might otherwise be made before this point, if the conditions are favourable for the implementation of the closed fuel cycle.

If at any time in the future a decision is made about the reprocessing of the spent fuel, then a fourth decision-making point arises in relation to the interim storage of the vitrified high level waste, that may take place either in Hungary or abroad.

The above-described decision-making points are shown in Figure 8. The figure clearly shows that several scenarios can be suggested for the closing stage of the nuclear fuel cycle the energetic reactors, the implementation of which can be imagined with a step-by-step decision-making.

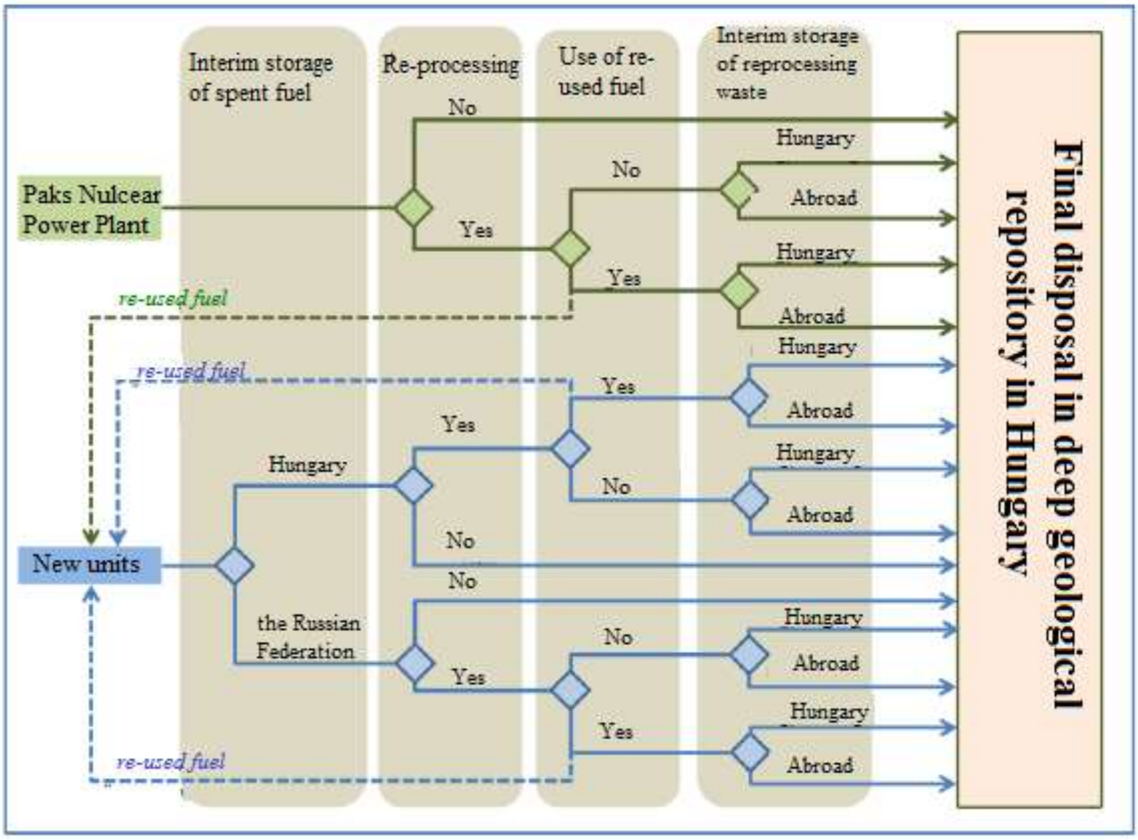


Figure 8: Illustration of decision-making points for closing the nuclear fuel cycle

5.3 Spent Fuel Treatment at the Budapest Research and Training Reactor

There are two spent fuel storage facilities available at the Budapest Research Reactor: the internal storage facility with a capacity of 596 fuel assemblies (additional free space for 190 pieces must be provided in accordance with the official requirements) and an external storage facility which can accommodate 2,256 fuel assemblies. As these figures show the external storage facility can alone accommodate all spent fuel assemblies. Both interim storage facilities are containers filled with water.

The original 24 fuel assemblies type EK-10 with 10% enrichment are stored in the active zone of the Training Reactor (see Section 4.3). Irradiated but not spent fuel is stored in the building of the Training Reactor. From a technical viewpoint, there is no difference between spent and irradiated fuels. The Training Reactor is provided with the technical background necessary for handling within the spent fuel building. A remote controlled crane equipped with a camera, 24 storage channels designed for the interim storage of irradiated fuel and intended to protect the reactor block concrete as well as a container provided with proper radiation protection and suitable for the handling the irradiated fuel assemblies are available for this purpose. Nevertheless, the removal of the spent fuel from the active zone and its storage within the building of the Training Reactor are not expected by the end of the lifetime of the Training

Reactor taken into consideration as a reference. Discharge after the final shutdown is expected to coincide with the removal of the spent fuel from the building of the Training Reactor.

According to the national programme, the Budapest Research Reactor will be shut down in 2023 and the Training Reactor in 2027 in a reference case. According to the plans, the spent fuel of both reactors will be delivered to Russia on the basis of "Agreement on cooperation between the Government of the Russian Federation and the Government of the Republic of Hungary in the delivery of the spent fuel of the research reactor to the Russian Federation" announced in Government Decree 2004/2008 of 19 August 2008. Under the agreement, the appointed representatives of the Russian and the Hungarian parties signed a private contract on the return of the fuel owned by the Budapest Research Reactor, including also the 24 fuel assemblies type EK-10 stored in the zone of the Training Reactor. They plan to extend this contract also to all spent fuel assemblies generated in the Training Reactor and the Budapest Research Reactor as well as to any fresh assemblies remaining at the end of the operating lifetime.

It is advisable to return the spent fuel to Russia in one phase. For that purpose, the interim period preceding the decommissioning of the Budapest Research Reactor must be extended by 2028-2029. The fuel of the Training Reactor may be transferred to the external interim storage facility of the Budapest Research Reactor after one year from the shutdown. Today, this can be solved with a container type TUK-19 – for which the drying technology of the fuel assemblies is available –, however, the decision must be made on the effectively used container in the years preceding the delivery. Then, all the fuels can be prepared for delivery to Russia on the area of the Budapest Research Reactor. If fresh fuel remains in any reactor at the end of the operating lifetime, then it must be delivered in the same phase but on the basis of other requirements.

Delivery to Russia must be made on condition that all by-products deriving from the processing of the spent fuel of the Training Reactor and the Budapest Research Reactor remain in Russia, which is allowed by Government Decree 204/2008 of 19 August 2008).

6 Final Disposal of Radioactive Wastes

The policy of final disposal of radioactive wastes has been specified by the national policy in the following way:

"The final disposal of low and intermediate level radioactive waste generated in our country must be implemented in radioactive waste storage facilities established in Hungary. The storage facilities must be designed to make sure that the site, the repository host rocks and the applied technical solutions jointly guarantee the insulation of the wastes from the living environment on the basis of the characteristics of the disposed waste."

Two disposal facilities operate in the country for the final disposal of the low and intermediate level waste; those of institutional origin are received by the Radioactive Waste Treatment and Disposal Facility (RWTDF) and those of the nuclear power plant by the National Radioactive

Waste Disposal Facility (NRWDF). The deep geological repository suitable for the receipt of high level and long-lived wastes is the phase of the selection of the site.

6.1 Disposal of Low and Intermediate Level Waste of Institutional Origin and its Schedule

By its nature, the use of radioactive materials has been accompanied also by the generation of radioactive wastes since the 1950s in Hungary. The experimental radioactive waste storage facility of Solymár was finished by 1960 as a temporary solution. The choice of the location of the experimental storage facility was not sufficiently grounded, and the technical solutions of the facility were also incomplete. Its capacity was fully used up soon, and therefore the establishment of a new radioactive waste storage-facility became necessary after ten years from its establishment.

6.1.1 Milestones of the Implementation of the RWTDF, and its Current Structure

The new facility – the RWTDF - was finished with a capacity of 3,540 m^3 in Püspökszilágy on 22 December 1976. The storage facility was technically implemented with a pool built close to the soil surface and a tube well.

In 1979-1980, the waste was transferred from the site of Solymár to the RWTDF, and then the site was cleaned and closed. Subsequently, continuous monitoring of the environment was provided, and the authority released the area for limited use.

In the absence of other provisions, in the initial period of its operation the RWTDF took over almost all radioactive wastes generated during the use of the nuclear technology for disposal, including thereby also long-lived radioactive wastes.

It was only natural at the time of the commissioning of the Paks Nuclear Power Plant that the radioactive wastes generated during the operation and decommissioning of the nuclear power plant should be finally disposed in Püspökszilágy. However, the volume of the wastes of the nuclear power plant substantially exceeded the capacity of the RWTDF, and the significant expansion of the facility to fully meet the demands the nuclear power plant was not feasible due to the conditions of the site. Therefore the delivery of the low level solid radioactive wastes of the Paks Nuclear Power Plant to Püspökszilágy was only a temporary solution. In its framework, out of the capacity of the RWTDF ca. 2,500 m^3 was occupied by the power plant between 1983 and 1989 and between 1992 and 1996. The storage capacity of the RWTDF of Püspökszilágy was expanded in the period between the deliveries. The total expanded storage capacity of the facility is 5,040 m^3.

The external storage space of the RWTDF intended for final disposal is a facility near to the surface, designed with technical barriers and constituted by concrete walled pools and steel lined tube wells as it is shown on figure 9. The disposal units of the facility are as follows.

Pools type "A"

> The RWTDF contains a total of 66 storage pools type "A". These pools are arranged in four rows of pools. Both conditioned (treated) and untreated wastes are disposed in plastic bags, in bulk or in metal barrels in the pools. In certain pools, the spaces between the waste packages were filled with low level contaminated cement mortar. In the recent years, only conditioned wastes in 200 l metal barrels and 1.2 m^3 steel plate containers are disposed in these disposal facilities.

Pools type "C"

> The disposal system type "C" contains 8 pools, each with a capacity of 1.5 m^3. The contaminated, conditioned (solidified) organic solutions were disposed in them.

Tube wells type "B" and "D"

> The disposal unit type "B" is constituted by 16 tube wells with 40 mm diameter and 16 tube wells with 100 mm diameter embedded into concrete foundations. The disposal system type "D" consists of 4 tube wells with 200 mm diameters. The tube wells are steel lined and 6 m long. According to the original practice, after disposal of the radiation sources in the wells, the wells were filled with cement mortar. The above practice of filling was abandoned to facilitate subsequent retrieval.

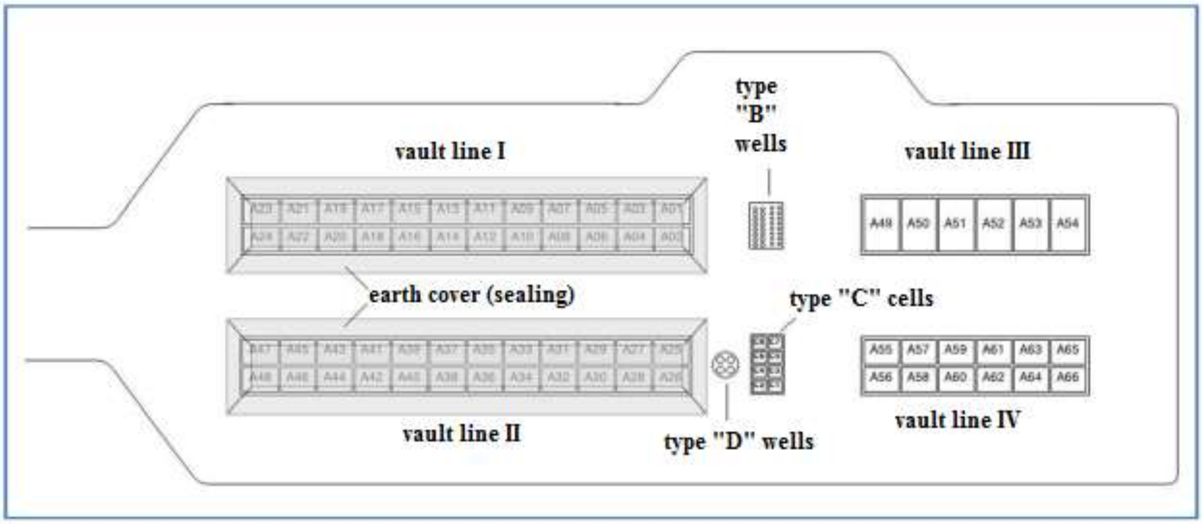


Figure 9: Facility unit of the RWTDF intended for final disposal

It was a significant milestone when the facility operating and licensing tasks related to the RWTDF were transferred to the legal predecessor of the PURAM in 1998. The work started with the full scale assessment of the safety of the waste disposal facility, the results of which are presented in Section 6.1.2.

Significant modernisations were started at the site of the RWTDF (which are detailed in Section 6.1.2). The PURAM performed supporting tests in relation to the feasibility of waste retrieval. Technologies (hot cab, sorting box, compressing press, cementing equipment) necessary for the safe treatment of the received institutional radioactive wastes and the already disposed and retrieved radioactive wastes were installed. Interim storage possibilities were provided in the plant building for radioactive wastes that cannot be finally disposed at the site. The basement level of the plant building is used for the interim storage of radioactive wastes in the following way.

Basement level storage of barrels

> The storage unit of barrels and containers is the largest part on the basement area. The barrels of wastes are stored in so-called carrying frames (4 barrels per carrying frame). 1.2 m^3 containers can be also stored in this storage unit. 3 carrier frames and 3 containers are stacked on each other, taking into consideration the internal height. The thickness of the reinforced concrete walls is adjusted to the earthquake safety requirements.

Interim storage facility containing tube wells

> The radiation source storage system constituted by 50 tube wells and located at the end of the basement corridor has been designed for the interim storage of gamma and neutron sources placed into torpedoes. Radiation sources with high half-life values (more than 30 years) may be disposed only in interim storage facilities.

Nuclear material disposal facility

> Nuclear materials[4] and neutron sources must be disposed in the nuclear material disposal facility. During the treatment of the nuclear materials, other chemical properties and hazard characteristics of certain nuclear materials were also taken into consideration beyond radiation protection aspects. The fire prevention issues and provision of terms of safeguards were the key factors as regards the storage of nuclear materials received for interim storage.

6.1.2 Safety Increase and Capacity Release

In the knowledge of the safety analysis finalised in 2002 we can state that the operation of the RWTDF and the safety of the environment are properly guaranteed until the end of the institutional control period, and the facility is suitable for the final disposal of (short-lived low and intermediate level) radioactive wastes of institutional origin meeting the criteria of

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[4] nuclear material: it is radioactive material which is or can be made capable of a self-sustaining nuclear chain reaction, particularly, uranium, thorium, plutonium and any material that contains one or more of the former materials at levels that can be cost-efficiently recovered, except for ores and ore wastes belonging to the fields of mining and ore processing.

acceptance. However, the safety assessment pointed out that after the closure of the institutional control, scenarios are possible as a result of which the previously disposed long-lived wastes may cause a radiation exposure of the inhabitants exceeding the dose limit. To be able to determine the range of wastes finally disposable in the disposal facility, a set of requirements of the acceptance of radioactive wastes was derived and its application was introduced on the basis of the safety assessment and in compliance with the international expectations.

Another issue related to the RWTDF is that the disposal capacity of the facility has, in fact, been exhausted. To make sure that the RWTDF is able to operate for additional several decades without any disturbances, the necessary capacity had to be created. Based on the results of the safety assessments, actions necessary for the safety expected on a long term and for the provision of additional storage capacities were outlined. As a result of the decision preparation process, a schedule of the programme intended to fully increase the safety and to release capacity was drawn, which started with a demonstration phase.

In the possession of the necessary preparatory studies and the permits, the implementation of the programme demonstrating the retrievability of the radioactive wastes started with the intention to be able to work out the technical details of the programme before making a decision on a large-scale intervention. It was also important to confirm that the planned activities would increase the long-term radiation safety to the expected extent and could be implemented in accordance with the specified workplace and environment safety requirements.

In the framework of the demonstration programme implemented between 2006 and 2009, a storage capacity of 280 m^3 was created by opening four pools. After resorting and - if necessary - conditioning and repackaging of the radioactive wastes, packages not meeting the acceptance criteria related for final disposal were temporarily stored (the waste volume required a storage space of 85 m^3). The finally replaced waste volume required a storage capacity of 170 m^3. To summarise the results of the demonstration programme affecting the four pools, we can state that the planned intervention was successful, since both objectives - identification and segregation of the major part of waste packages critical from the aspect of long-term safety and the creation of a free capacity - were met. The retrieval of the radioactive wastes - even in the case of the half concreted pool - was relatively easy to implement.

6.1.3 Commissioning of the RWTDF, Treatment of Radioactive Wastes

The normal operating activities of the site in Püspökszilágy include the receipt of radioactive wastes, treatment (sorting, qualification, conditioning), interim storage and final disposal of the wastes. From the spring of 2007, the normal operating activity was expanded with the so-called safety increasing programme, during which radioactive wastes disposed formerly but not in compliance with today’s requirements were retrieved, sorted, conditioned and stored again.

The process of further treatment of the wastes varies depending on the types of the wastes received by the operating plant and retrieved during the safety increase measures. The radiation sources, the nuclear materials, the compactable and non-compactable components of the mixed solid wastes and the liquid wastes are separately treated.

Radiation sources that have been used up or become necessary are packaged, repackaged and then cased in the hot chamber of the operating plant. Here the radiation sources are put into stainless steel containers, so-called “torpedoes” for storage in the tube well. The interim storage of the radiation sources is implemented mainly in the tube wells at the basement level of the operating building. The high level and long-lived radiation sources are received here. Only radiation sources containing isotopes with low half-life values are inserted in the tube wells on the outdoor storage area. The torpedoes ready for placement are handled by means of a service container within the site.

The nuclear materials (plutonium, uranium, thorium) and a part of the neutron sources (^{239}Pu-Be, ^{252}Cf) must be placed in the nuclear material disposal facility. Wastes containing nuclear materials can be only temporarily stored in the RWTDF within a designated storage facility. The incoming nuclear material or the nuclear material retrieved during the safety increase measure are repacked if necessary.

The incoming waste package or the waste package retrieved during the safety increase measure must be resorted if necessary. This is necessary to be able to separate the compactable and non-compactable components of the mixed solid wastes, and to remove a component not allowed by the waste acceptance criterion related to the final disposal it if is contained in the waste package. The waste is sorted in the sorting box.

The compactable wastes are compacted by a special press into 200 litres metal barrels. The non-compactable components are placed into barrels or 1.2 m^3 plate containers and fixed with cement.

Liquid radioactive wastes received or generated in small volumes at the site are collected in containers placed at the basement level, and when the collection containers are filled they are solidified by means of an installed cementing unit.

Decision is made on the interim storage or the final disposal of the radioactive wastes after the qualification of the radioactive wastes. If the wastes placed into barrels or containers complies with the waste acceptance criteria specified for final disposal then they are finally disposed in pools type “A” on the outdoor storage area. If the waste package does not meet the disposal requirement then it is forwarded to the interim storage facility at the basement level of the operating building of the RWTDF. According to the plans, the wastes stored in the interim storage facility will be finally disposed in the deep geological repository when it is commissioned.

The site has been operated by the PURAM since the mid of 1998. The site received radioactive wastes from more than 370 companies and institutions during the last 15 years. On an average, ca. 50 waste acceptances take place in a year, but their number may reach 100 in certain years. In most cases, they are accepted outside the site, and the staff of the RWTDF delivers them to the site. The volumes of radioactive wastes and used up sealed radioactive sources received during the last 15 years are shown on diagrams indicated on Figures 12 and 13.

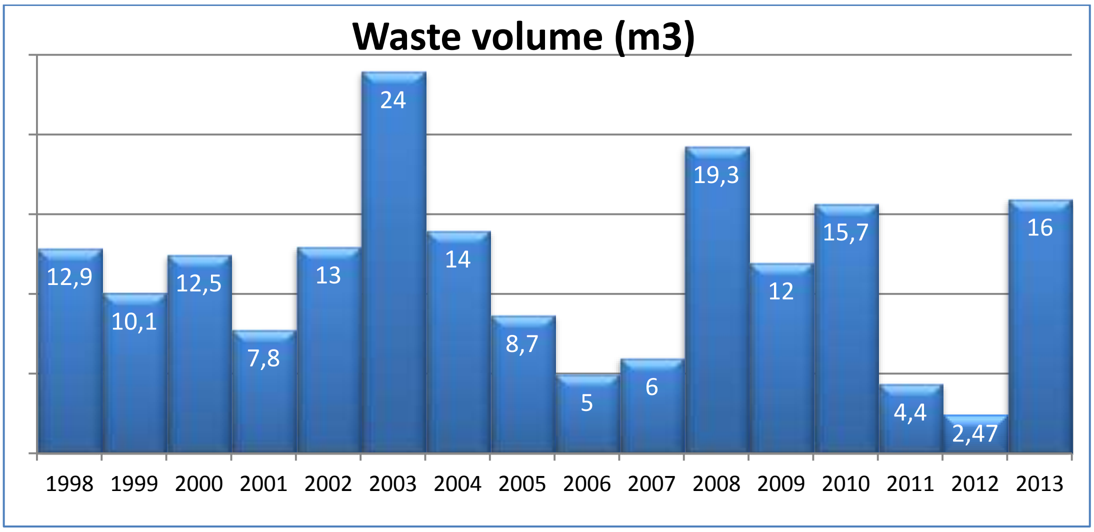

Figure 10: Waste volumes delivered to the RWTDF in the last years

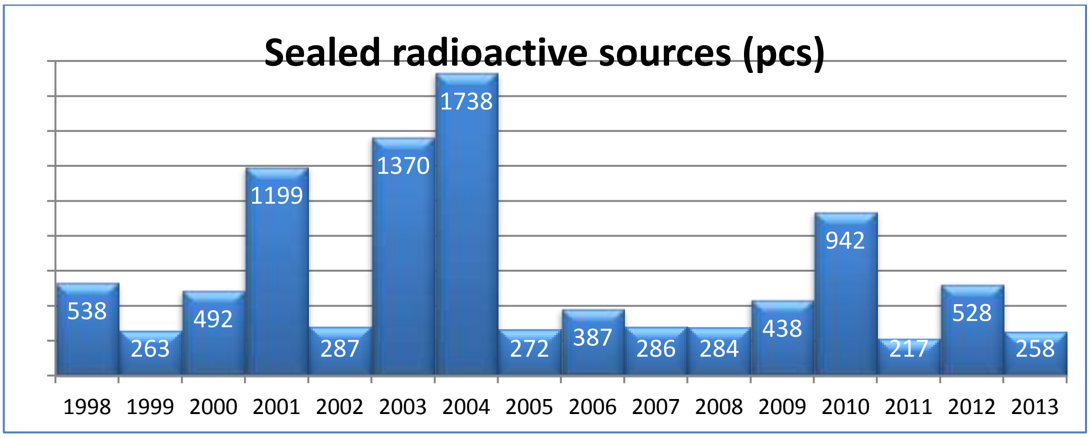

Figure 11: Sealed radioactive source volumes delivered to the RWTDF in the last years

6.1.4 The Closure Concept of the RWTDF, Institutional Control

The storage pools type "A" were covered in the following way after a pair of pools were filled. The current soil cover of rows of pools I and II of the storage area is 2 m high from the road level and has been created with 45 degree slopes on two sides. The slope is ca. 1% on the upper part. The local clayey soil excavated during the landscaping is its material according to the original plans. It is intended to reduce doses on the plant area and to protect the concrete structures against external effects, rain and frost. In its current condition, the soil cover perfectly meets the above objectives. Due to its fabrication technology, it is characterised by a 3 layer structure. A 10 to 15 cm thick top soil layer is the upper layer, with a ca. 60 cm non-compacted loose layer under it. A ca. 1.3-1.5 m thick compact clayey layer is above the head of the storage pools.

The current soil cover must be considered temporary. The final closure concept meeting the requirements specified in the safety assessment must be established in the future. Already the current soil cover limits the penetrating moisture content to a value of ca. 10 mm/year, and when it is supplemented the expected limit-value of several mm/year will be achievable. During the safety assessments performed until now, it was assumed that the moisture content penetrating through the soil cover would not exceed 5 mm/year. To confirm the compliance of the final closure, a demonstration programme has been anticipated for the decades preceding the planned closure of the disposal facility.

The surface radioactive waste disposal facilities are extremely sensitive to unintended human intrusion. Institutional control is proposed by the international recommendations to limit this. The parts of the disposal system accessible from the surface must be serviced after the closure of the disposal facility. During this, the surface drains must be cleaned, the soil cover protected against deep rooted plants and the fence serviced. In addition, the control of the site and environment of the radioactive waste disposal facility will be continued in the form of monitoring. Based on the effective legislation, the length of the so-called active institutional control is minimum 50 years. In the current international practice, the length of the active institutional control is 100-300 years in the case of surface disposal facilities, and therefore the PURAM makes its assessments on the basis of a 150 year active institutional control period. Subsequently, the fence must be demolished, and no further maintenance or control of the site will be necessary.

However, the location and characteristics of the facility will remain known (e.g. in the land office records, databases) during the period of the so-called passive institutional control, and then it is assumed that the information related to the facility will be forgotten.

6.1.5 Future Milestones of the RWTDF

Continuation of the programme intended to increase safety and release capacity is the major long-term task in addition to the normal operation in the RWTDF. For that purpose, a large hall of light structure provided with a crane and an internal room for waste treatment must be built. The hall is intended to cover one row of pools (24 pieces of 70 m^3 pool) and to provide proper working conditions for the retrieval and performs also the radiological and environmental functions necessary for the work. According to the current plans, the hall will be finished by the beginning of 2017.

As regards rows of pools I and II, i.e. 48 pools, it is recommended to implement full waste retrieval for 24 pools and partial waste retrieval for 20 pools (4 pools have been already processed during the demonstration programme).

In the next phase of the safety increasing programme, the contents of rows of pools III and IV will be retrieved, processed, replaced, and shallow storage pools type “C” will be abandoned.

The method of retrieval of the radiation sources in tube wells types “B” and “D” and of their transfer to the deep geological repository must be founded and prepared as the closure of the safety increasing programme. The tube wells must be abandoned.

Long-term tasks related to the RWTDF are contained in Table 16.

Table 16: Long-term tasks related to the RWTDF

Timetable	**Activity**
2015-2017	construction of a hall of light structure
2017-2022	implementation of retrieval, processing and replacement in relation to chambers A01-A24 of the row of pools I
2023-2029	implementation of retrieval, processing and replacement in relation to chambers A24-A48 of the row of pools II
2030-2037	retrieval, processing and replacement of the contents of rows of pools III and IV and abandonment of the shallow storage pools type “C”
2038-2039	establishment of an experimental pool cover
2040-2060	operation of an experimental pool cover
2061-2064	recovery of radiation sources in tube wells types “B” and “D” and preparation for the transfer to the deep geological repository
2064-2066	transfer of the long-lived radioactive wastes stored in the facility to the deep geological repository, preparation for the final soil cover of pools type “A”
2067	completion of the final closure of the facility, commencement of the active institutional control

6.2 Disposal of Low and Intermediate Level Waste of Nuclear Power Plant Origin

Since the expansion of the facility of Püspökszilágy to an extent sufficient to meet the total demand of the nuclear power plant was not feasible, the National Project was launched in 1993 with the intention to find a solution to the final disposal of low and intermediate level radioactive waste of nuclear power plant origin.

6.2.1 Milestones of the Implementation of the NRWDF, its Current Structure

Preparation for the choice of the site started in the framework of the National Project. The whole area of the country was reviewed on the basis of the data of the literature, and then preliminary field explorations were made to identify geological objects suitable for surface and subsurface disposal in the promising regions, where it was supported also by the inhabitants. It is important to note that in addition to technical suitability, social acceptance was also an important aspect, and therefore a combined site selection process was implemented.

The closing document of the geological, technical safety and economic studies recommended additional studies for the subsurface disposal in the granite in the region of Bátaapáti in 1996. Additional sites considered suitable for the establishment of the surface disposal facility were also taken into consideration as alternatives (in the regions of Udvari, Németkér and Diósberény). The region of Bátaapáti was considered suitable also because it is located not far from the nuclear power plant, on the same bank of the Danube. Therefore, in 1997, a decision was made to start more thorough explorations in the region of Bátaapáti. The surface geological explorations were made in several phases until 2003. Meanwhile, several preliminary safety assessments were also made, supporting the feasibility of the disposal facility and guaranteeing safety.

At the end of 2003, a closing report was made on the geological explorations, and according to its main finding “The site of Bétaapáti meets all the requirements specified in the decree, and therefore it is geologically suitable for the final disposal of low and intermediate level radioactive wastes”. The competent geological authority, the Southern Transdanubian Regional Office of the Hungarian Geological Service gave an opinion on this document and approved it in a decision.

The subsurface exploration plan made for the period of 2004-2007 was intended to designate the rock volume receiving the disposal facility. The subsurface exploration works started with the deepening of the slopes in February 2005.

In 2005, an opinion poll was held in the village at the initiative of the municipal council of Bátaapáti. With a high participation rate (75%), nearly 90.7% of the voters agreed with the construction of a low and intermediate level waste disposal facility in Bátaapáti. In its decision on the preliminary, theoretical consent necessary for the commencement of the preparatory activity for the establishment of the low and intermediate level radioactive waste disposal facility and on the extension 85/2005 (23 November 2005) of the operating period of the Paks Nuclear Power Plant, on 21 November 2005, the Hungarian Parliament gave a theoretical consent to the commencement of the activity preparing the establishment of the low and intermediate level waste disposal facility on an area already previously qualified as geologically suitable, on the basis of the requirement of the Nuclear Act.

The establishment of the NRWDF is implemented in several phases, and the commissioning and the licensing of operation of the individual finished facility parts are adjusted to the phases of the establishment.

In the first phase, the surface facilities of the NRWDF, the central and the technological buildings were completed by the mid of 2008. Thereby, on the basis of the permit for commissioning issued on 25 September 2008, the acceptance and technological storage of a part of the solid wastes accumulated in the Paks Nuclear Power Plant (compacted mixed solid wastes, packed into 200 litres barrels) were enabled in order to make preparations for the final disposal.

The first two storage chambers (I-K1 and I-K2) were constructed, and the servicing technological systems were built by 2012, in the second phase of the implementation. The space intended for the final disposal - and located 250 metres under the surface - is accessible via to approach cuts, each with a length of 1,700 m and a slant of 10%. Within the so-called slopes, the western one is intended for the delivery of the radioactive wastes as a part of the controlled zone, while the eastern one is intended for the further construction of the disposal facility.

After the success of the necessary operation licensing procedure, the final disposal of the radioactive wastes in storage chamber I-K1 could be started. Since the drifting work is performed by means of drilling and explosions, storage chamber I-K2 serves as a buffer between the operating chamber and the chamber under drifting in accordance with the official requirements.

6.2.2 Operation of the NRWDF

The radioactive wastes are delivered from the Paks Nuclear Power Plant to the NRWDF by road. The barrels are lifted to the transport vehicle in so-called carrying frames in units of four, and a total of 16 barrels are simultaneously delivered. When the consignment is received in the NRWDF, the vehicle drives to the technological building, the 2.5 t crane lifts and then places the carrying frame in the room part of the technological hall designed for this purpose (see figure Figure 12). The maximum number of the 200 lit. barrels that can be placed in the technological storage space is 3,000.

All essential information generated in connection with the individual waste packages are electrically recorded in the waste registry system where all packages are labelled with an ID. During the acceptance of the radioactive wastes, the holder of the licence of the disposal facility confirms compliance with the waste acceptance requirements with the necessary controls.

Figure 12: Technological storage of radioactive wastes in the surface facility of the NRWDF

For the purpose of final disposal, the waste containing barrels are placed into reinforced concrete containers. Nine barrels are put into each container. Then the lid is fixed on the container, and the cavities in the container are filled up with inactive concrete. Fillings are made on a vibration table to fill up all cavities and to ensure homogeneity. After 7 days of consolidation, the finished reinforced concrete containers are finally disposed in subsurface storage chambers, where 19 containers may be placed in each section of the chamber, which is illustrated by Figure Figure 13

Figure 13: Placement of reinforced concrete containers in storage chamber I-K1 of the NRWDF

Currently (01.01.2015), 2,231 pieces of 200 lit. barrel are temporarily stored in the surface technological building, while 3,249 pieces of 200 lit. barrels have been finally disposed in 361 reinforced concrete containers. Backfilling of the storage chamber has not yet taken place, it will be performed prior to the closure of the chamber field.

6.2.3 Milestones of the Further Construction of the NRWDF

The system of cuts of the first chamber field of the NRWDF is presented on Figure Figure 14Based on our current knowledge, six storage chambers can be established in the storage unit; four chambers perpendicularly to the disposal facility interconnecting cut on the eastern side and two chambers on the western side, nearly in parallel with it.

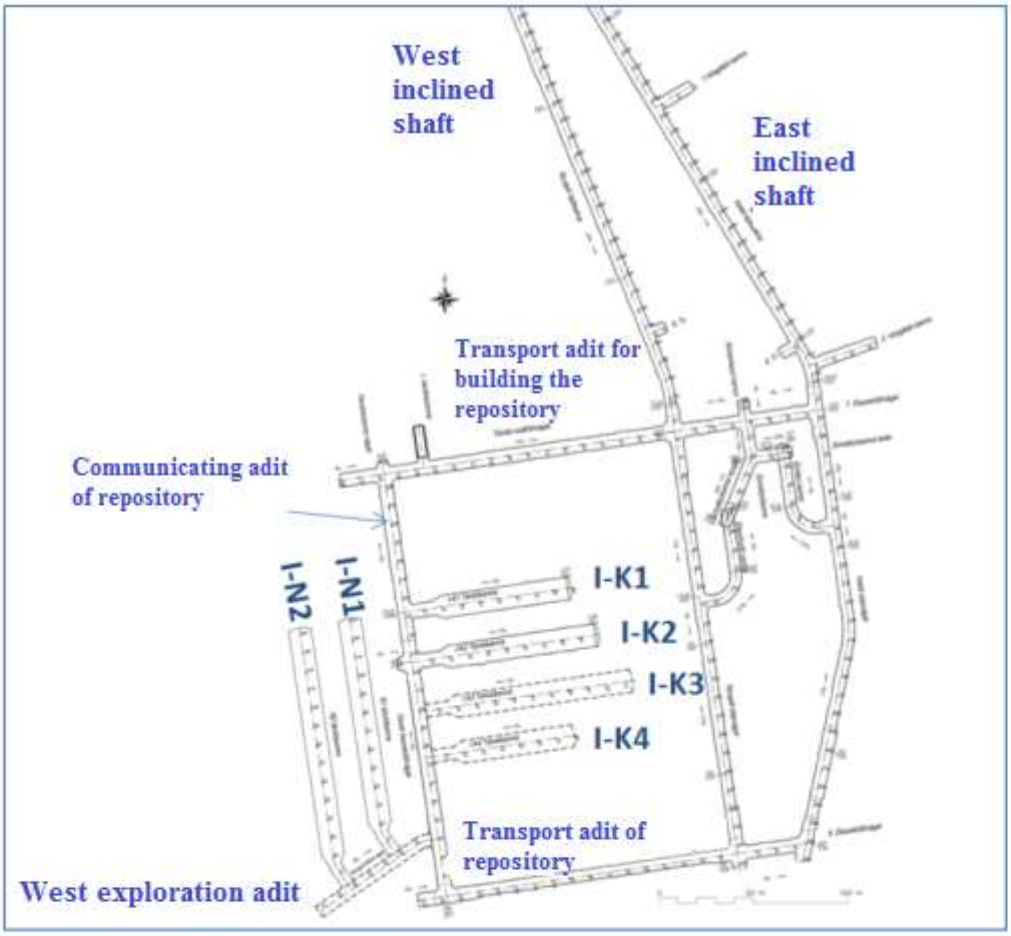

Figure 14: System of cuts of chamber field I of the NRWDF

The foundation of the further construction of the NRWDF started simultaneously with the commissioning of the first storage chamber: this involves the development and licensing of a new storage concept and placement system that allows the creation of as many storage spaces as possible and the most efficient space utilisation of the storage chambers in the available storage unit.

The new placement concept is based on a thin-walled steel container, into which four barrels - containing solid radioactive wastes - are put on the area of the nuclear power plant, and the empty space is filled with active cement pulp made from the liquid wastes of the nuclear power plant. This unit is called a compact waste package.

In the previous placement concept, the reinforced concrete container was a part of the engineering barrier system, and its functions are now taken over by the reinforced concrete pool built into the storage chambers. The compact waste packages will be stored in this pool.

As it was previously noted, storage chamber I-K2 was established together with chamber I-K1 with the same section size of 96 m^2. Compact waste packages can be placed in 6 columns and 5 rows in each section in the reinforced concrete pool to be constructed in it. After optimisation, a section form with an area of 115 m^2-was found, in which compact waste packages can be placed in 7 columns and 6 rows in each section, which is illustrated by Figure 15.

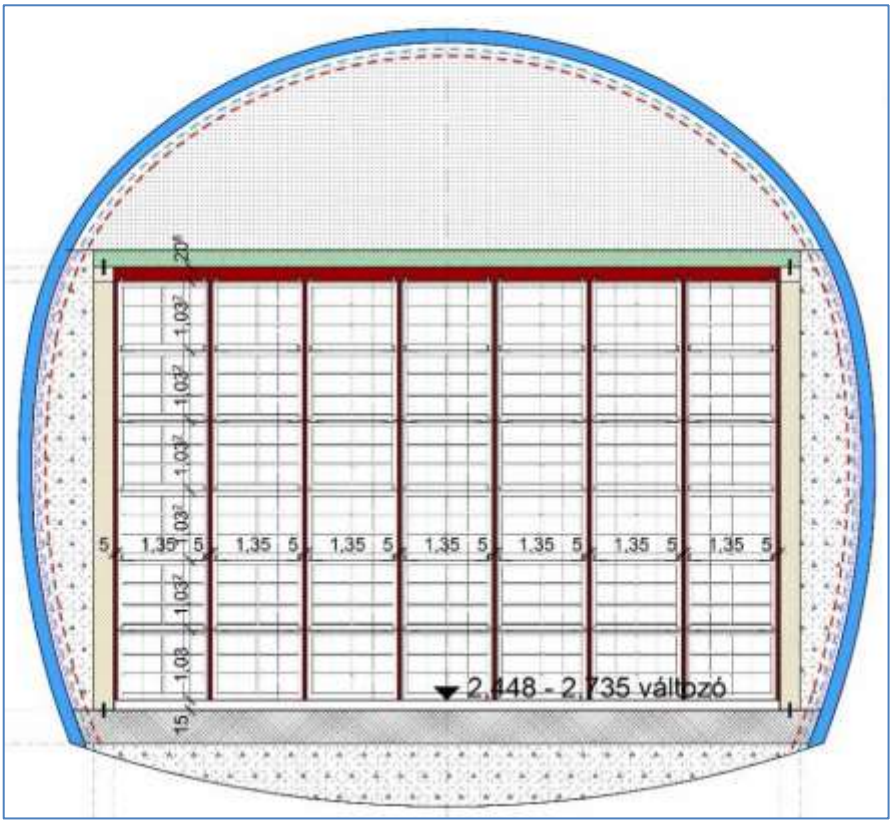

Figure 15: Placement system optimised for the placement of compact waste packages

The efficiency of the placement is further increased by the fact that the placement of barrels containing low level solid wastes in reinforced concrete pool I-K2 and on the top of the closed reinforced concrete pools was foreseen, and then its feasibility was confirmed with a safety assessment.

With the planned optimisation of the placement system, the rate of radioactive wastes can be increased from 19% to nearly 50% in the useful volume of the storage chambers. Thereby ca. twenty billion forints can be saved, mainly as a result of the reduction of the number of storage chambers to be drifted.

Due to the modifications involving the above placement system, the environmental and establishment licences of the NRWDF were modified on the basis of the supporting analyses and the safety assessments. Storage chambers I-K3 and I-K4 are being drifted in the possession of the currently valid licences. Subsequently, the reinforced concrete pool must be built in chamber I-K2 so that it can be commissioned in 2017 in compliance with the delivery phase of the Paks Nuclear Power Plant.

The additional expansion of the facility must be planned in compliance with the delivery schedule of the wastes of the nuclear power plant. Based on this, the expected dates of the commissioning of the additional chambers and the key milestones of the disposal facility - in view of the wastes of the currently operating four nuclear power plant blocks - are contained in Table 17.

Table 17: Future milestones of the NRWDF in view of the currently operating four blocks

Schedule	Activity
2017	commissioning of chamber I-K2
2020	commissioning of chamber I-K3
2026	commissioning of chamber I-K4
2035	commissioning of chamber I-N1
2042-2061	retention, conservation, monitoring (no wastes are delivered here in this period)
2062-2069	commissioning of storage chamber I-N2, then the expansion of the disposal facility, delivery and final disposal of the decommissioning wastes
2081-2084	decommissioning and closure of the facility
2085	beginning of the institutional control

6.2.4 The Closure Concept of the NRWDF, Institutional Control

After the final disposal of the waste package last received, decontamination and demolition (and utilisation for other purposes) of the surface buildings used for the acceptance, qualification, processing, packaging and buffer storage of wastes and of the technological systems contained in it as well as removal of any industrial and radioactive contaminations from the site must be implemented on the basis of the current closure plan. All radioactive wastes generated during these activities must be finally disposed in the part of the subsurface disposal facility intended for this purpose. Then, the final closure (abandonment) of the subsurface disposal facility must be commenced.

The space between the reinforced concrete containers and the cut wall within storage chamber I-K1 is backfilled after the filling up of the first chamber field. Backfilling is made with concrete, to which granolith is added. In the case of the new chambers containing compact waste packages, backfilling is made simultaneously with the placement of wastes, in stages. In the plans, plugs are foreseen on the so-called neck part connecting to each storage chamber interconnecting cut.

According to the plans, backfilling of the servicing and approach cut system is made with granolith, and sectionalising plugs made from concrete and bentonite will be integrated at certain places. Within these plugs, the so-called dam plugs are of highlighted importance. The hydrogeological modelling supporting the closure concept has shown that the closure of the impervious ruptured zones crossed by the approach cuts (slopes) is a key task for the long-term radiological safety of the disposal facility. According to the advanced concept plan of the closure, so-called dam plugs must be designed at these crossings. Concrete plugs are planned to be integrated at the opening point to reduce the probability of any subsequent unintended human intrusion.

The subsurface disposal facility of the NRWDF dimensioned for the disposal of low and intermediate level wastes is, in fact, a geological disposal facility in view of the 250 m depth. In the case of radioactive waste disposal facilities to be located at such depths, the probability of any unintended human intrusion is much lower than in the case of surface disposal facilities; based on the international recommendations, it is advisable to take it into account as a beyond design basis incident. Based on these aspects, 50 years have been foreseen as an active institutional control period in the plans in the case of the NRWDF. During this, the operation of a limited monitoring system is planned, which is solely intended to detect any anomalies.

The long-term retention of the knowledge and information related to the location and characteristics of the facility must be ensured also beyond the active institutional control period. This requirement was taken into account during the planning of the relevant information systems (e.g.: waste records). After the passive institutional control period, it is assumed that the location and the characteristics of the facility will be forgotten.

6.2.5 The Impact of the New Blocks on the Disposal of Low and Intermediate Level Waste of Nuclear Power Plant Origin

The low and intermediate level waste generated during the operation and decommissioning of the two nuclear power plant blocks to be established at the site of Paks have significant impacts on the design of the NRWDF from both quantity and time schedule aspects.

A sufficient storage capacity can be established for the disposal of the operational low and intermediate level wastes of the new nuclear power plant blocks in the remaining storage chambers available in the chamber field I of the NRWDF. However, in that case a storage capacity necessary for the low and intermediate level waste deriving from the demolition of the four blocks of the Paks Nuclear Power Plant must be provided with the expansion of the NRWDF by the beginning of the 2060s. There are several potential areas suitable for the expansion within the area currently qualified suitable from a geological aspect. An exploration activity was planned to support the final choice, which is detailed by Section 8.3.2.

The fact that the new blocks will operate until the mid of the 2080s followed by decommissioning must be taken into account. Delivery of low and intermediate level waste deriving from the decommissioning of the active building units and technological systems to the NRWDF is expected until 2100. If the interim storage of the spent fuel of the new blocks is implemented in Hungary - taking into account at least 40 years of cooling of the spent fuel before the final disposal - then preparations must be made also for the disposal of the wastes generated during the operation and decommissioning of the interim storage facility. Based on the above it is concluded that the extension of the operation of the NRWDF by 20 to 40 years is expected as a result of the new blocks.

6.3 Treatment of High Level and Long-Lived Wastes

There has been no final decision (see Section 5.2) made in Hungary for the closing section of the nuclear fuel cycle in relation to the energy reactors. The selection of the location of a deep geological repository is in process in addition to the interim storage of spent fuel. This disposal facility will be necessary in the case of the introduction of any fuel cycle closure method. Therefore Hungary is committed to dispose the high level and long lasting radioactive wastes in a stable, deep geological repository within the area of the country. According to the uniform international position, such a disposal facility is suitable for the direct disposal of the spent fuel (which is considered A high level waste in that case) and also for the acceptance of secondary high level wastes generated during the processing of the spent fuel. The establishment of a deep geological repository offers a final solution in both cases, irrespective of what decision is made on the closing phase of the fuel cycle.

6.3.1 Preliminaries of the Choice of the Site, the Current Situation

In Hungary, the exploration programme related to the final disposal of high level radioactive wastes started in the framework of the National Project at the end of 1993 - with the study of the Claystone Formation of Boda found in Western Mecsek (hereinafter referred to as BCF) - which continued as an independent exploration programme after its completion in March 1995. Studies implemented in the underground laboratory (exploration cut created from the system of cuts of the uranium mine of the region) established in the BCF were the heart of the short-term exploration programme (between 1996 and 1998). In this phase of the exploration, the Hungarian specialists were supported also by the colleagues from the Canadian Atomic Energy of Canada Limited (AECL). As a result of the closure of the uranium mine, the underground laboratory previously accessible via the mine, was abandoned at the end of 1998. The target-oriented studies of the short-term exploration programme confirmed that the dimensions, isolation properties and geotechnical characteristics of the BCF are acceptable even at an international level, and are worth further exploring.

The PURAM created in 1998 reconsidered the concepts related to the design of the disposal facility, and had carried out formation qualifying screening for the whole area of the country in 2000. The initial database of the screening included all registered Hungarian formations occurring between 300 and 100 m under the surface. This survey was made by means of a combined two-stage screening method. In the first step (negative screening phase), formations obviously unsuitable from geometric, special and procedural aspects were screened by using very mild criteria. 20 formations remained on 32 regional units by the end of the this phase. In the second step, in the phase of the detailed assessment, all remaining formations were qualified on the basis of uniform assessment aspects.

As a result of the national screening, the formations assessed in detail were classified into three categories: “recommended for further exploration”, “for consideration if necessary” and “not recommended”. 6 rock bodies were classified into category “recommended” on 9 regional units, within which the occurrence of the BCF in Western Mecsek was prominent according to the specified criteria and also the reliability. The occurrence of the BCF in Gorica region was at the 5th place, and classified also into category “recommended”. Two occurrences of the Clay Formation of Kiscell and the Complex of Baksa were also at the beginning of the scale. Thus according to the result of the survey, the BCF proved to be the most promising rock for the reception of the high level wastes.

Based on the above, an exploration programme was made to designate the locations of a site suitable for the disposal of the Hungarian high level and long-lived radioactive wastes and of a new underground research laboratory in Western Mecsek. After the necessary approval procedure, the field exploration started in 2004, however, it was interrupted due to funding difficulties in 2006.

Simultaneously with the commencement of the explorations, the concept plan for the disposal of the spent fuel of the nuclear power plant and of the research reactor as well as of other high level and/or long-lived radioactive wastes was drawn in 2004. The plan provided a preliminary concept for the creation of the waste packages, the establishment of the casing plant and the schematic layout of the disposal facility together with the applicable engineering barriers. This plan served as a basis for subsequent cost estimates.

Based on the BCF exploration information obtained before 2004, a simplified safety assessment was made by the beginning of 2005 with the major intention to preliminarily assess the suitability of the repository host rock or formation. The preliminary assessment confirmed that due to their large masses, isotope binding abilities, low porosity and low permeability the formations of the BCF seem to be suitable for the reception of the waste disposal facility.

The content, financial and schedule concept updating the long-term programme of the BCF exploration was made in 2008. This plan foresaw a geological exploration divided into phases in compliance with the international practice, which is constituted by three surface and two subsurface phases. The field activity implemented between 2004 and 2006 is called stage 1 of surface phase I.

In 2012, the PURAM drew an exploration plan related to stage 2 of surface phase I, which was approved by the Pécs District Mining Inspectorate in May 2013. The research relaunched in 2014 is the continuation and completion of stage 1 interrupted in 2006. The purpose of the exploration is to give a general site qualification of the BCF, to acquire geological data and information necessary for the safety assessment, and to reduce uncertainties. The target area can be limited and the detailed plan of the next research phase can be made on the basis of the integrated evaluation planned by the end of the research phase.

The area of the geological exploration made in Western Mecsek was 87 km^2, it is indicated on Figure 16. On the figure, the delineation of the exploration area is indicated by the green line, while the surface view is indicated by the brown line, where the BCF lies in a favourable situation (at a depth between 500 and 900 m).

The direct study of the claystone formation and its environment, the documentation and sampling of the formation, the field measurements are allowed first of all by the exploration facilities (shallow and deep wells, trench). Within them, the deep wells are of highlighted importance since direct geological information can be obtained by means of these wells at the level of the disposal facility, at a depth of several hundreds of metres. The well cutting is documented, sampled and laboratory tests are made on the samples. Field geophysical, geotechnical and hydrogeological measurements are made in the wells.

The exploration area is “transilluminated” with a surface geophysical method, seismic reflection sections. These sections allow the spatial extension of the well information.

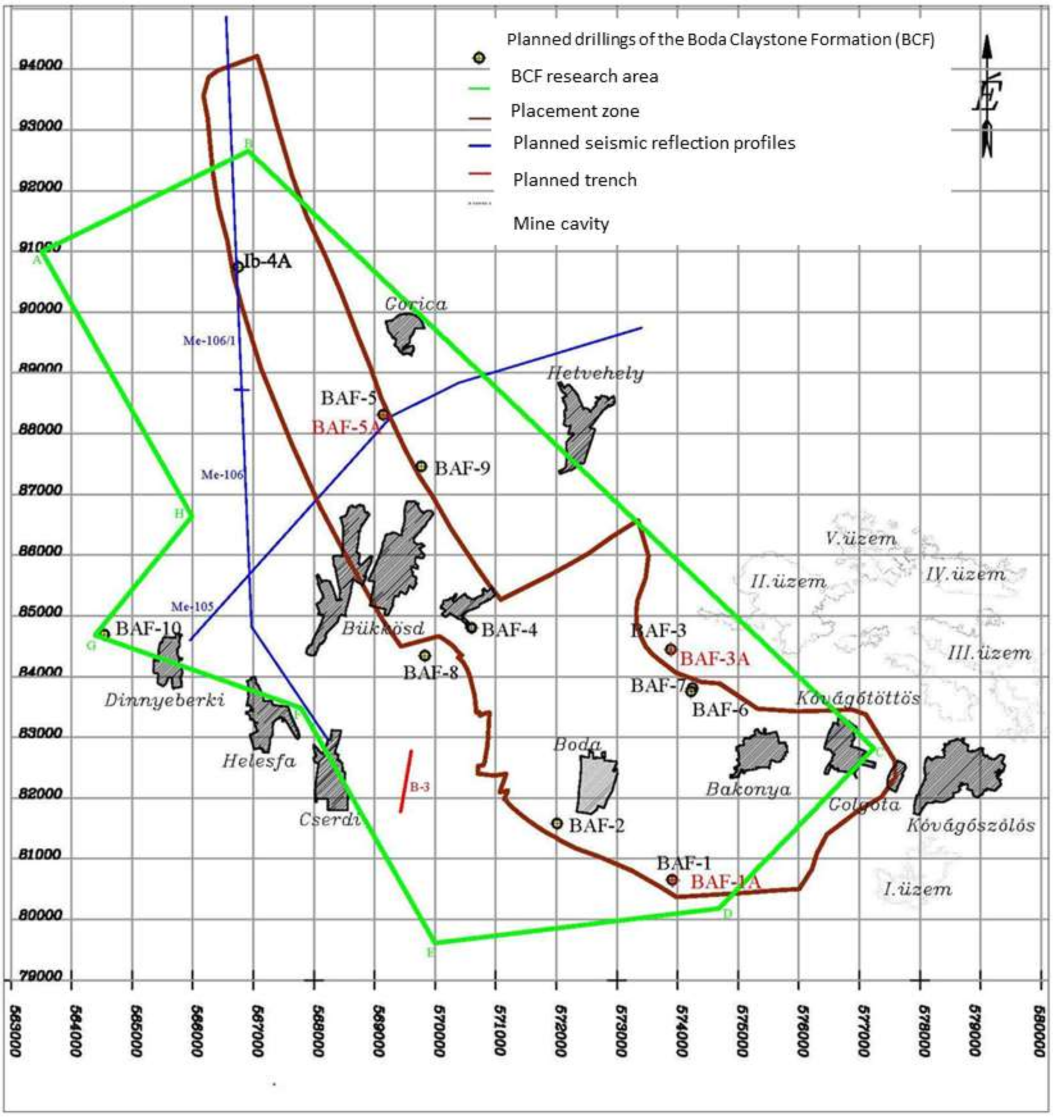

Figure 16: Exploration area of stage 2 of phase I of the BCF (illustrated in UNP coordinate system)

6.3.2 Schedule of the Establishment of the Deep Geological Repository

According to the international practice, the implementation of depth geological disposal facilities suitable for the reception of high level waste and spent fuel lasts for decades. Programmes launched at the end of the 1970s and now considered advanced have foreseen the commissioning of the first depth geological disposal facilities in Europe by 2025. This is reflected also by the vision of the EU technology platform (IGD TP[5]) established to promote the implementation of the geological disposal.

The time needed for the implementation of the disposal facility is 51 years in the concept updating the long-term programme of the BCF exploration in compliance with the

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[5] Implementing Geological Disposal Technology Platform

international experiences. The schedule of the geological exploration and of the establishment of the disposal facility divided into phases is illustrated on Figure 17.

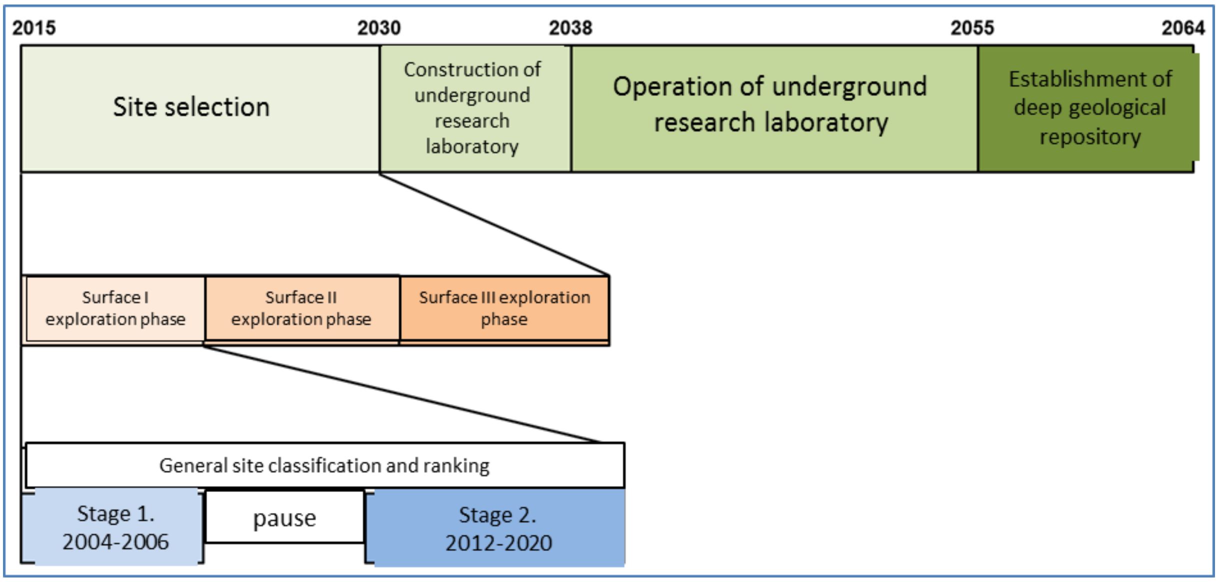


Figure 17: Schedule of the Implementation of the Deep Geological Repository

The purpose of the surface exploration is to select the site of the disposal facility both on the surface and under the ground. The purpose of surface exploration phase I is to give a general qualification of the site and to select the target area. At the end of the phase, tracts suitable for the disposal must be ranked within the current exploration area of 87 km^2. Exploration phase II continues on the narrowed exploration area, at the end of which the location of the deep geological repository and the area of the relating surface site can be designated and qualified. Surface exploration phase III is intended to make preparations for the subsurface research laboratory.

In the Hungarian programme, it has not been decided if the research laboratory will be part of the subsequent disposal facility. The relevant decision can be made in view of the results of the surface explorations and of the preliminary layout of the disposal facility. Irrespective of the decision, the establishment of the research laboratory is a significant milestone in the process of the implementation of the disposal facility. Application for the preliminary theoretical approval of the Parliament, specified in the Nuclear Act, will be necessary at this point for the commencement of the preparatory activities for the facility.

6.3.3 The Impact of the New Blocks on the Design of the Deep Geological Repository

The new nuclear power plant blocks have a decisive effect on the design of the deep geological repository from three aspects. The increasing volume of the spent fuel and the larger size of the spent fuel assemblies must be taken into account during the planning of the disposal facility, and expandability must be also an important aspect on the one part. On the other part, the new blocks are expected to operate until the mid of the 2080s, and the spent fuel - or the high level waste deriving from reprocessing - require several decades of cooling, and therefore the expected lifetime of the depth disposal facility might be up to 50-60 years instead of 20 years. The third aspect relates to the possibilities of the closure of the nuclear fuel cycle. As it was presented in Section 5.2, in addition to the direct disposal taken into consideration currently as a reference, several different cycle closure options are possible in the future, and the probability of the choice of the latter is increased if the process is optimised for six blocks.

During the exploration of the site and the planning of the disposal facility, the circumstances of the reprocessing wastes must be also examined in the case of alternatives containing also processing. This results in the requirement that maximum flexibility must be provided in relation to the waste deriving from the closing phase of the nuclear fuel cycle during the selection of the site of the depth disposal facility. This is allowed by the use of the “do and see” principle. The decision points related to the consideration are presented in Section 5.2.3, while the advance is presented in the continuation of the selection of the site of the deep geological repository (see Section 6.3.2).

Before making decisions on the closing phase of the nuclear fuel cycle, the impacts of the individual cycle closure options on the costs of the establishment of the depth disposal facility must be determined in detail in the framework of the comparative cost-efficiency analyses.

7 Decommissioning of the Nuclear Facilities

Based on the effective national legislation, a preliminary decommissioning plan must be drawn for nuclear facilities and it must be reviewed every five years. This must confirm that the facility can be safely decommissioned at the level of the technologies. Another major purpose of the decommissioning plan is to determine the expected costs of the specific facility and the volume of wastes deriving from the demolition.

The decommissioning plans of the national nuclear facilities constituting a major strategic element of the inner system of correlations and the schedule of the national programme are presented in the following sections.

7.1 Decommissioning of the Paks Nuclear Power Plant

7.1.1 Preliminaries

The preparatory activities related to the decommissioning of the Paks Nuclear Power Plant started with the drawing of a study covering the decommissioning of blocks 1 and 2 in 1993. The Preliminary Decommissioning Plan drawn in 1997 covered already the decommissioning of block 4 and ISFS. These plans were made by the licensee of the facility, the Paks Nuclear

Power Plant. In 1998, the PURAM took over the performance of preparatory activities related to the decommissioning as a result of the changes in the legislation, and from then the updating of the Decommissioning Plans are financed by the Fund.

At the beginning, there were no sufficient experiences and information on the decommissioning of nuclear facilities in Hungary, and therefore the PURAM found it necessary to obtain an expert opinion on the ready documents to which the expert assistance of the International Atomic Energy Agency (IEAE) was requested. The documents were reviewed in three topics:

- creation of the decommissioning database structure;
- activation calculations of the reactor vessel and its internals;
- review of the decommissioning plan.

IEAE expert opinions were made as a result of the reviews, and its recommendations were taken into consideration during the additional preparatory activities.

Between 1993 and 2012, the preliminary decommissioning plans ordered by the Paks Nuclear Power Plant and the PURAM studied still 6 different decommissioning options. Since they were very similar in view of both costs and waste volumes, a decision was made to reduce the number of the options. As a result, the subsequent analysis studied only the following internationally accepted and applied two options:

- immediate decommissioning;
- delayed decommissioning with the safeguarding of the primary circuit for 20 years.

A complex evaluation of the above two decommissioning options was made during drawing of document “Foundation for the New Programme of the Treatment and Disposal of National Radioactive Wastes and Spent Fuel”.

The system of cost codes intended for the calculation of the decommissioning costs of the nuclear facilities and drawn by three international organisations (OECD Nuclear Energy Agency, International Atomic Energy Agency, European Commission) was used as a basis for the determination of the decommissioning costs of the facility.

As part of the review made between 2012 and 2014, the radiological baseline assessment of the technological systems and building structures of the nuclear power plant was made, the activation calculations of the reactor biological protections were reviewed, and certain chapters of the decommissioning plan were updated in 2012.

The preferred option of the decommissioning of the Paks Nuclear Power Plant foresees the safeguarding of the primary circuit for 20 years and then its decommissioning. The ultimate objective of the decommissioning activities is to make the site usable under certain limitations.

The new nuclear power plant blocks to be established at the site of Paks are expected to operate until the mid of the 2080s. It is advisable to subsequently harmonise the decommissioning strategies of the 6 blocks located at one site, which may lead to a slight increase of the safeguarding period in the case of the current 4 blocks.

7.1.2 Timing of the Decommissioning Process

The period from the shutdown of the blocks to the completion of the decommissioning activities can be divided basically into four stages. The schedule of the individual stages is shown on Table 4.

The first stage called an interim period starts from the date of the shutdown of block 1 and lasts until the delivery of the last spent fuel assembly to the ISFS. Considering the time interval between the starting of the blocks and assuming that they will be shut down in the order of their starting, this period is ca. 10 years.

A valid decommissioning licence must be in available by the end of the interim period and the handing over and acceptance of the licensee rights will be take place between the Paks Nuclear Power Plant and the PURAM also at that time.

The interim period will be followed by phase I of the decommissioning, which includes the safeguarding of the whole controlled zone for 20 years and the decommissioning/demolition of the free zone in the preferred decommissioning option.

The activated and contaminated technological elements and building structures will be decommissioned and demolished in phase II. The planned period of phase II is 8 years.

Phase II is basically constituted by the demolition of the already inactive buildings, cutting of the reactor equipment, the treatment of the wastes as well as the rehabilitation of the area and the final radiation protection assessment. The planned period of phase III is 11 years.

Table 4: Schedule of the delayed decommissioning option of the Paks Nuclear Power Plant

Stages - task	Start	End
Interim period	01.01.2032	31.12.2041
Decommissioning Phase I - Safeguarding, demolition of free zone	02.01.2042	30.12.2061
Decommissioning Phase II - Decommissioning, demolition of the activated and contaminated volume	02.01.2062	31.12.2069
Decommissioning Phase III - Demolition of the inactive volume	01.01.2070	31.12.2080

7.1.2.1 Interim period

The MVM Paks Nuclear Power Plant is the licensee of the facility in the interim period, with the main task to keep the nuclear safety and to deliver the spent fuel assembles to the ISFS after cooling.

This is when the operation of the facility is finished and prepared for safeguarding. Decontamination operations are performed as part of it to reduce the dose rate. This includes, among others, the decontamination of the autonomous circuit, the removal of the operating media, the cleaning of the wall and floor covers of the rooms.

Additional main tasks of the licensee in the interim period are as follows:

- review of the operating instructions;
- drawing of a staff reduction plan;
- processing of operating wastes;
- delivery of the retained assemblies to the ISFS;
- assistance in the handing over-acceptance of the licensee's rights.

In addition to the above, the radioactive waste processing activities must be terminated, and such wastes must be delivered to the NRWDF.

The radiological survey necessary for the preliminary planning is an essential element of the activities to be performed in the interim period.

In addition to the radiological survey necessary for the planning of the decommissioning works, the hazardous materials (flammable, explosive, toxic materials, asbestos) must be also surveyed in the interim period.

On the basis of Government Decree 314/2005 of 25 December 2005 on environmental impact studies and integrated environment use permits, an environmental licence is necessary for the decommissioning activities. An environmental impact study must be performed prior to the drawing of the final version of the Decommissioning Plan after the preliminary survey.

Handing over and acceptance of the licensee's rights between the MVM Paks Nuclear Power Plant and the PURAM take place in two steps (blocks 1-2, and then 3-4). Simultaneously with the licensing procedures, setting up of the project management organisation liable for the decommissioning starts within the organisation of the PURAM. The project management organisation is fully liable for the management of the decommissioning process. Its highlighted tasks include licensing, selection of suppliers, contracting, performance of investment and sales tasks as well as training. The tasks of the organisation end after the completion of the decommissioning activities.

7.1.2.2 Phase I

Phase I involves mainly the safeguarding of the primary circuit, while the facilities and infrastructure intended for the decommissioning and demolition of the inactive volume, followed by the decommissioning and demolition of the free zone from the mid of the phase also take place in this phase. Buildings in the yard and a part of the turbine hall are also involved in the decommissioning and demolition of the inactive volume.

The buildings in the yard have no additional functions in the decommissioning process, and therefore they are fully decommissioned and demolished, contrary to the turbine hall where only the work area treating radioactive wastes (active waste treatment facility) is created after the necessary reconstructions. Establishment of the interim inactive waste treatment facility (disassembly plant) is necessary for the performance of the works in this phase. This facility processes inactive construction materials deriving from the demolition, and the interim storage of the inactive wastes of the technological decommissioning also takes place here.

Another facility necessary for the implementation of the decommissioning activities of phase II is the storage building of large equipment to be built also in this phase.

7.1.2.3 Phase II

The technological systems of the primary circuit will be decommissioned at the beginning of phase II. It is a complex activity consisting of the on-site decommissioning and cutting of the technological systems (mechanical, electric and control techniques) on the one part, and the retrieval of high level wastes retained in the tube wells and the treatment of the waste volumes obtained from them on the other part.

The reactor equipment are removed at the beginning of this phase in the following way:

1) The most active parts of the reactor equipment are the so-called reactor baskets which are intended to retain the fuel during operation. According to the calculations, the reactor baskets will be considered high level wastes after several decades of storage, and therefore they are placed into specific containers, and will finally disposed in the deep geological repository after several decades of storage on the site.
2) The other internals of the reactor equipment are replaced into the containers. Biological protection rings are fastened to the parts of the containers around the active zone, and then new closing lids are placed on them, and after the welding and external painting of the cut studs they are retained in a new building (storage building of large equipment) at the site until final cutting.
3) The other large equipment, including the steam generators, are cut with an endless saw not far from their places of installation.

Radiological qualification of the materials available in the controlled zone and their classification by the rate of contamination are made in connection with the waste treatment activity. The purpose of the qualification is to specify the optimal decontamination procedure for the individual system elements. After the necessary decontamination procedures, the wastes are conditioned and then radiologically qualified. The waste treatment operations will be performed at a working place established in the turbine hall (active waste treatment facility), including the interim storage of the radioactive waste packages.

After the removal of the technological systems, the contaminated buildings (activated concrete structures in the vicinity of the reactor container, building structures involved in the flow of the primary medium and the structural elements of the tube wells) are removed, and then the surfaces of the building structures and rooms are decontaminated.

At the end of phase II, the decommissioning activities are intended to reach an inactive condition of the buildings of the Paks Nuclear Power Plant, which must be confirmed by the final radiological survey.

The final radiological survey to be implemented at the end of phase II does not include the building of large equipment containing the reactor containers.

7.1.2.4 Phase III

The demolition of the already completely clean buildings takes place in phase III, including the controlled zone. The main and auxiliary buildings, the health building and the utilities of the site are demolished in this period. Cutting of the reactor equipment belongs also to this phase (between 2077 and 2078).

The rehabilitation of the site, the demolition of the building of large equipment and the final radiological survey of the site take place in the last two years of phase III.

7.2 Decommissioning of the ISFS

The ISFS was established for the interim storage of the spent fuel generated during the operation of the Paks Nuclear Power Plant in the neighbourhood of the power plant, and its design lifetime is 50 years. The central reception building and the relating technology were commissioned together with the first three chambers in 1997, the licence for operation was issued by the competent authority in 1998. The design lifetime of the facility must be extended with 25 years until 2072- for the extension of the lifetime of the Paks Nuclear Power Plant and in accordance with the planned date of commissioning of the deep geological repository, which is subject to a relevant official licensing procedure.

Only one regularly reviewed decommissioning plan covering both facilities existed for the decommissioning of the Paks Nuclear Power Plant and the ISFS until the division of the organisation operating the two facilities in 2000. The first completely independent Decommissioning Plan of the ISFS was drawn in 2010 after the division.

The above decommissioning plan of the ISFS studies only one so-called immediate decommissioning version, which is closely adjusted to the decommissioning of the Paks Nuclear Power Plant due to cost-efficiency aspects.

The ultimate objective of the decommissioning of the ISFS - similarly to the Paks Nuclear Power Plant - is to make the site usable under certain limitations.

7.2.1 Timing of the Decommissioning Process

The decommissioning activity will start in 2073 after obtaining the licence for decommissioning and removing all the spent fuel, and will be finished in 2077 according to the plans. The decommissioning can be divided into three phases illustrated on Table 19.

Table 19: Stage of the immediate decommissioning option of the ISFS

Stages	Activities	Start	End

Stages	Activities	Start	End
Phase I	Provision of technical and administrative terms for decommissioning	01/01/2073	26/04/2073
Phase II	Decommissioning/demolition of the contaminated systems and building structures	26/04/2073	29/06/2074
Phase III	Demolition of the inactive buildings, landscaping and final radiological survey	29/06/2074	26/05/2077

In phase I, the technical and administrative terms necessary for the decommissioning of the contaminated system and system elements and for the demolition of the building structures (for the removal of the contaminated surface coats) are provided. As a result of the process, the infrastructure necessary for the implementation of the decommissioning is set up and the staff and the equipment are made available in addition to the physical protection of the site.

During phase II of the decommissioning, the radioactively contaminated and inactive systems and system elements are decommissioned and the contaminated building structures are demolished for which preconditions of implementation must be provided. The various activities may be performed in adherence to the requirements of the so-called decommissioning licence issued by the nuclear safety authority. The final state of phase II is characterised by the decommissioning of the systems and system elements, the removal of the contaminated surface coats and the general elimination of the radioactive contamination in relation to the ISFS and the site. For that purpose, the technical and administrative terms necessary for the implementation and the physical protection of the site must be provided.

In phase III of the decommissioning, the buildings and buildings structures are demolished, landscaping is made on the terrain and the site is prepared for further use in addition to the demolition of the infrastructure intended for the decommissioning, the removal of the staff and the equipment, the liquidation of the physical protection and the official licensing procedure intended to terminate the official supervision.

The calculations of the preliminary decommissioning plan show that during the decommissioning of the ISFS ca. 500 pieces of 200 l barrels (i.e. ca. 100 m^3) of low and intermediate level waste will be generated, but no high level wastes are expected to generate.

7.3 Decommissioning of the New Blocks

During the planning of the new nuclear power plant blocks, it is an important requirement to generate the minimum radioactive wastes during the abandonment of the nuclear power plant, taking into consideration also the international recommendations. This purpose is served by the provision of the Hungarian legislation stating that the availability of a preliminary decommissioning plan is a precondition for the acquisition of the licence for establishment, which must be reviewed regularly (every 5 years) until the end of the lifetime.

In accordance with the international practice, the immediate decommissioning option is taken into account for the decommissioning of the 5-6 blocks. Planned phases of decommissioning:

- shutdown of the nuclear power plant blocks (6 months),
- preparations for the decommissioning (5 years),
- disassembly of the equipment and reclamation of the area (10 years).

The estimated volumes of wastes generated during the decommissioning are shown in Section 3.2.6.

7.4 Decommissioning of the Budapest Research Reactor

2023 has been specified as a reference date of the shutdown of the Budapest Research Reactor for the preparation of the national programme, however, the date of the shutdown will be finalised by the Hungarian Academy of Science and the Government in view of the financial possibilities.

The operating period is the preparatory design phase of decommissioning. This is performed by the operating organisation, the Hungarian Academy of Sciences Centre for Energy Research (hereinafter referred to as the HAS CER). From 2005, a preliminary decommissioning plan was made with reviews (updating) every 5 years, which is Volume 6 of the Final Safety Report of the Budapest Research Reactor. The final decommissioning plan must be drawn and submitted to the atomic energy surveillance body for approval 1 year before the final shutdown of the reactor. A chapter of the final decommissioning plan, the radiological mapping of the site may be implemented only after the shutdown and the removal of the spent fuel. The decommissioning plan will be supplemented with this chapter in the interim period.

The shutdown will be followed by a 2 year interim period according to the preliminary decommissioning plan, and then by a one and half year demolition and decommissioning phase, at the end of which the area will be returned to the owner, the Hungarian Academy of Science together with the buildings on it, in a radiologically clean condition. We must note that if the Training Reactor and the Budapest Research Reactor are shut down in 2027 and 2023, respectively, then the interim period must be extended until 2028-2029 due to the causes detailed in Section 5.3. The decommissioning is planned to be implemented according to the following schedule.

During the 2 year interim period, the site will be operated still by the HAS CER. Major tasks related to the decommissioning in this period:

- removal of all operating (active, inactive and hazardous) wastes from the site,
- delivery of all fuels (fresh and spent) from the site to Russia,
- radiological mapping of the site,
- decontamination,
- establishment of a temporary cutting workshop in the reactor hall,

- establishment of storage places and pavilions for the storage, packaging and control of radioactive wastes in the reactor hall,
- training programme for the staff of the site and third party contractors,
- conservation, maintenance.

At the end of the interim period, the site is handed over to the PURAM designated by the Nuclear Act as liable for the decommissioning.

During the demolition and decommissioning phase - starting directly after the interim period and lasting for ca. one ad half years - all the technological systems of the reactor are demolished together with the relating experimental equipment, waste storage facilities, the radiation protection and physical protection system, and the loaded concrete biological protection of the reactor container. The buildings and the air chimney are not demolished.

During the decommissioning of the Budapest Research Reactor, ca. 670 m^3 inactive, 10 m^3 inactive hazardous, 260 m^3 low and intermediate level solid radioactive, and 180 m^3 liquid radioactive wastes are generated under the decommissioning of the reactor. After compaction and cementing, 260 m^3 low and intermediate level radioactive wastes, 10 m^3 hazardous inactive wastes, and 270 m^3 communal wastes must be removed from the site. The inactive wastes are disposed on a communal landfill, the hazardous wastes are disposed on a landfill for hazardous wastes, and the radioactive wastes are disposed at the site of the PURAM in Püspökszilágy. No high level wastes are expected to generate during the decommissioning of the Budapest Research Reactor.

7.5 Decommissioning of the Training Reactor

During the planning of the decommissioning of the Training Reactor, several special aspects must be taken into consideration, where the fact that the reactor is situated inside Budapest, on the area of the BUTE, is the most important. This means that during the scheduling of the decommissioning activity, the normal operation of the vicinity of the site, i.e. the operating rules and the everyday education activities of the campus of the BUTE must be taken into consideration to avoid any impact on them.

The limitations of the delivery routes, that is their load-bearing capacity and the upper limit of the consignment, are an additional special circumstance. According to the plans, it is not necessary to fully demolish the building since beyond the reactor there are also laboratories not closely related to it (isotope laboratory level “B”, X-ray laboratory etc.) which may operate also after the demolition of the zone and its relating structural elements.

As a precondition of the commencement of the decommissioning, no fuel may be left in the reactor building. The technologies of the decommissioning and the necessary conditioning are developed at an international level.

The decommissioning activity is expected to start 3 years after the final shutdown, following the interim period. This includes the demolition of the biological protection block of the reactor, the removal of the servicing and safety equipment related to the reactor as well as other equipment located in the reactor and related to various reactor physical experiments.

According to the preliminary plans, it is not necessary to demolish the building structure during the decommissioning of the Training Reactor, and only modifications necessary due to the removal of the biological protection block providing radiation protection for the reactor should be performed on it. As a result, the building will be subsequently usable. Based on this, the active water treatment system, the radiation protection control and signal system and the physical protection system would remain in place. Low and intermediate level wastes generated during the decommissioning - in an estimated volume of 50 m^3 - will be delivered to the site of the RWTDF in Püspökszilágy, qualified, conditioned and then disposed by the licensee of the decommissioning, the PURAM. No high level wastes are expected to generate during the decommissioning of the Training Reactor.

8 Research & Development Activities Related to the Implementation of the National Programme

Activities related to the programmes planned for the treatment of the radioactive wastes and spent fuel generated on the area of Hungary and for the decommissioning of the nuclear facilities are in different states of progress, but they are common in that their successful implementation requires research & development tasks to be implemented to some extent. The most important research & development needs are summarised in the following sections, which are not exhaustive.

The Sustainable Nuclear Energy Technology Platform was created in Hungary in 2010, which developed the vision of national nuclear research & development, its strategic research plan and implementation plan. A part of the research & development tasks summarised in these documents relate to the area discussed in Section 8.1, the interim storage of the spent fuel, while another part relates to the closing stage of the nuclear fuel cycle presented in Section 8.2. The performance of the research & development activities detailed in the above plans is important from the aspect of both the implementation of the radioactive waste and spent fuel treatment programmes and the maintenance of the national nuclear competencies.

8.1 Research & Development Tasks Related to the Interim Storage of Spent Fuel

The major research & development tasks are considered already solved as regards the interim storage of the spent fuel, however, the demand on the extension of the operating time of the ISFS, the foundation of the storage of the failed assemblies in the facility, and finding a solution to the interim storage of the spent fuel generated in the new blocks are additional tasks.

Extension of the operating time of the interim storage facility of the spent fuel

Due to the planned extension of the operating time of the nuclear power plant and the modified schedule of the disposal of the spent fuel, preparations must be made for the extension of the operating time of the ISFS. Parameters and systems essential from the aspect of the extension of the operating time of the disposal facility must be specified during these preparations. In addition, admissibility of a storage period exceeding 50 years from the aspect of the integrity of the spent fuel assemblies must be also examined. For that purpose, studies necessary for the support of further operation and related to the facility and to the spent fuel assemblies must be identified. The specified studies must be implemented in due time.

Interim storage of the spent fuel of the new nuclear power plant blocks

The establishment of an interim storage facility independent from the current interim storage facility of the spent fuel assemblies might be necessary in connection with the installation of the new blocks. There are several technically proven options of dry storage of fuel deriving from the retention pool: e.g. storage in containers, silos or chambers. Based on safety and cost-efficiency aspects, it should be assessed into which storage system the spent fuel assemblies of the new reactors should be most properly placed.

Foundation of the storage of the failed assemblies in the ISFS

The so-called spinning procedure intended to detect the failed fuel assemblies has been recently developed in the Paks Nuclear Power Plant, and therefore the detectability has further improved. Analyses made to date on the storage of failed assemblies in the ISFS were based on several conservative assumptions. The necessary research & development activities must be performed for the support of the licensing procedures, by means of which the source strength of the failed assemblies can be accurately determined, and the uncertainties treated with conservative assumptions in the removal mechanisms can be reduced.

8.2 Research & Development Tasks Related to the Closing Section of the Nuclear Fuel Cycle

Several strategic options are available for the closing stage of the nuclear fuel cycle according to the previous sections. The closure of the fuel cycle is one of the greatest challenges for the nuclear industry, the solution of which requires more intensive research & development activities. Hungary tries to get involved in these works, among others, in the following fields:

Possibilities of the utilisation of the spent fuel with the currently operating technologies and fourth generation reactors

A numeric model allowing a long-term simulation of the fuel cycle must be established within this task. For that purpose, processes taking place during the production of the fuel, its burning, interim storage, reprocessing in the nuclear power plant reactors, and the final disposal of the wastes must be described. The model calculations should make it possible to find how the volume, heat generation and radiotoxicity of the radioactive wastes to be finally disposed can be reduced with various reprocessing technologies, use of advanced fuel (e.g.: MOX, REMIX), and fourth generation fast reactors. This model serves as a scientific-technical basis for the subsequent decision-making.

Specification of technical measures allowing the recovery of the fuels deriving from reprocessing in a VVER reactor

The use of reprocessed fuel is limited for several reasons. On the one hand, their presence affects the controllability of the reactor for a physical reason, and therefore the interventions of the control and safety protection system must be designed in accordance with other requirements. On the other hand, the “fresh” fuels coming to the nuclear power plant are radiant to a slight but not negligible extent due to the reprocessing, and therefore the relevant requirements specify other technical solutions than those considered sufficient in the case of the generally used uranium-dioxide containing fuels. Based on foreign examples, the technical terms under which the new blocks of Paks may use also the subsequently reprocessed fuel must be specified in cooperation with the supplier of the new blocks of Paks.

Among the fourth generation reactors, the fast reactors are of highlighted importance from the aspect of the fuel cycle, which are an advance in comparison to thermal reactors as regards the utilisation of both natural uranium and the secondary actinides generated in the spent fuel. The sodium cooled fast reactor is closest to the industrial implementation, while the lead cooled fast reactor and the gas cooled fast reactor are considered alternative technologies. From the aspect of the research & development objectives related to the closing stage of the nuclear fuel cycle it is important to establish a proper professional potential in connection with all fast reactor types in Hungary, with a special regard to the fact that the lead cooled ALFRED and the gas cooled ALLEGRO experimental reactors are planned to be implemented also in the Eastern Central European region. Based on the contribution of the national specialists, the ALLEGRO reactor and the research & development work supporting the establishment of the fuel laboratory should be highlighted.

The ALLEGRO reactor

Among the potential fast reactor technologies, the gas cooled fast reactor (hereinafter referred to as the GCFR), more closely the ALLEGRO reactor intended to demonstrate the operability of the GCFR technology attracts currently the most attention at national level. The reactor is assumed to be built in Slovakia. The GCFR is one of the alternative fourth generation fast reactors considered feasible from the aspect of transmutation and fuel breeding. These reactors play an important role in the recovery of the accumulated spent fuel.

The operability of the GCFR technology will be demonstrated with the ALLEGRO reactor. In 2010, the Czech, Hungarian and Slovakian nuclear research institutions signed a cooperation agreement on the preparation of the implementation of the ALLEGRO reactor (with French support), and the Polish nuclear research institute also joined it (2012). In 2013, the participants created the V4G4 organisation for the coordination and external representation of the cooperation.

The preparation stage (2014-2018), the licensing, construction and commissioning stage (2018-2030), the operation and decommissioning of the reactor are the milestones of the implementation programme. In the first phase of the reactor's operation, a zone built from traditional fast reactor fuels will operate, and the experiments on the advanced ceramic fuels suitable for operation at high temperatures and to be used in the second stage will also take place then.

Fuel test laboratory

The establishment of a fuel test laboratory is a very important element of the national nuclear research & development plans. The fuel test laboratory would be built at the site of the Paks Nuclear Power Plant. Its double purposes are: the study of physical and chemical changes caused by the radiation in the fuel rods used in the new blocks of Pask, and based on this, the improvement of the efficiency of the fuels - in cooperation with the supplier of the fuels - on the one hand, and the improvement of the fuels of the fourth generation reactors, mainly the future ALLEGRO reactor, its qualification for use in the reactor on the other hand. Radiations necessary for the development of the fuels of the ALLEGRO reactor may take place in the Budapest Research Reactor. The fuel test laboratory would be a research infrastructure operating as a nuclear facility and meeting Hungarian, regional and European demands. During the first implementation stage of the investment (2015-2018), planning, licensing, establishment and commissioning tasks should be performed. During the second implementation stage of the investment (2024-2030), the second group of equipment would be purchased and commissioned. The works performed in the fuel test laboratory can be divided into two periods as regards the normal operation. In the first operation stage (2019-2029), the fuels to be used for the ALLEGRO reactor are qualified, then the experiments related to the new special ceramic coated fuels to be developed for the ALLEGRO reactor can be also started. Works intended for research purposes related to blocks 5 and 6 of the Paks Nuclear Power Plant can be started also in this period. As regards the tasks, the second stage of the normal operation starts from 2030. The first radiated fuel rods are expected to come from the new blocks of Paks and the ALLEGRO reactor in this period. This is when the study of the fuels deriving from the new nuclear power plant blocks to be established in Paks can be also started. The fuel laboratory may play a key role in the establishment of the Hungarian expertise related to the closure of the nuclear fuel cycle.

8.3 Research & Development Tasks Related to the Disposal of Radioactive Wastes

8.3.1 Research & Development Demands of the Operation and Safety Improvement of the RWTDF

The disposal units of the RWTDF are situated above the groundwater level (in the unsaturated zone). The groundwater level is by 10-15 m under the storage pools. The concept model applied by the safety assessments for the spread in the unsaturated zone must be finalised in view of the previous results.

The final closure of the disposal facility has an important role in guaranteeing the long term safety of the surface waste disposal facilities. A demonstration experiment must be planned, and then implemented and operated for the determination of the concept and order of layers of the final cover. The final cover concept can be designed on the basis of the processing of the results of the demonstration programme and the operational experiences.

The abandonment concept of the outdoor tube wells (types B and D) - containing radiation sources which will be finally disposed in the deep geological repository - must be specified. For that purpose, the method of the removal, cutting and repackaging (containerisation) of the tube wells and the necessary radiation protection equipment must be designed. The special road transport containers necessary for the transfer of the storage tube pieces and the tube containers (torpedoes) exceeding the 10 mSv/h dose rate to the final disposal facility must be planned.

A radiological assessment must be performed on a long run in the framework of the planning of the decommissioning of the surface facilities of the disposal facility, based on which the volumes of the generated radioactive wastes can be accurately determined.

8.3.2 Research & Development Demands of the Operation and Expansion of the NRWDF

The storage of the low and intermediate level radioactive wastes of nuclear power plant origin has been basically solved with the establishment of the disposal facility in Bátaapáti in Hungary. Nevertheless, the implementation of several additional research & development tasks is reasonable, which are intended mainly to optimise the disposal system, to increase the safety of the operation, and to forecast and finalise the processes of the period following the closure of the disposal facility.

No additional chambers will be built in the NRWDF for a few years after the establishment of storage chambers I-K3 and I-K4. Therefore at the end of the current construction phase, the geological-tectonic, hydrogeological and geotechnical information related to the site and the space use experiments must be summarised, with a special regard to the compliance of the cut support and the injection.

The volumes of the decommissioning wastes of the currently operating blocks of the Paks Nuclear Power Plant and the operational and decommissioning wastes of the new nuclear power plant blocks to be established in the future require the expansion of the NRWDF. Exploration by means of subsurface wells must be performed to designate the optimal expansion direction.

A detailed assessment must be made in relation to the expected volumes and main components of the low and intermediate level wastes in connection with the establishment of the new nuclear power plant blocks. The trace element contents of the planned cement and additives must be examined already before the construction, and proper formulations must be provided to minimise the activity and volume of the decommissioning wastes. The isotope composition and activity of the concrete structures situated near the reactor vessel, the reactor equipment and the container must be determined by means of three dimension neutron flux calculations to assess the decommissioning waste volumes. The method of disposal of wastes (mainly concrete and metal) generated mainly during the decommissioning of the nuclear power plants and belonging to the very low level category to be introduced according to the plans in the approach cuts of the NRWDF must be simultaneously analysed.

According to Section 6.2.4, the so-called dam plugs play a key role in the safety of the phase following the closure of the NRWDF. The conceptual plans of the design of the plug have been completed. The detailed plans of the design of the dam plug must be drawn on the basis of additional material tests, and then the on-site demonstration and study programme intended to certify the implementation and compliance of the dam plug must be implemented.

The regular monitoring of the environmental condition of the disposal facility, the geological and hydrogeological monitoring must be continued, since the prognoses related to the period following the closure can be finalised based on these data. The transient processes of the establishment and closure of the NRWDF performed in stages must be dealt with in detail. The thermodynamic characteristics of the development phases following the final closure of the disposal facility, the behaviour of the design radionuclides in the individual development phases must be determined more accurately, and the periods of the individual phases must be assessed. The complex impact of the various long term climate changes and the possibility of the three phase spread of the radioactive isotopes must be studied. The dose calculations related to the various development scenarios must be updated based on the latest international information and the new numerical modelling possibilities during the safety reviews to be performed periodically.

8.3.3 Research & Development Tasks Related to the Establishment of the Depth Disposal Facility

A research framework programme must be developed for the research, development and demonstration activities related to the final disposal of high level and long-lived radioactive wastes, which is approved by the HAEA. The research framework programme includes also the geological research framework programme intended to certify the geological suitability of the site. The research framework programme to be developed must cover the following topics:

The volume, isotope inventory, physical and chemical properties of the radioactive wastes to be disposed in the disposal facility, the possible design, development of the waste forms, the material, size, long term behaviour of the various waste packages (disposal containers) must be determined, taking into account the decision possibilities related to the closure of the nuclear fuel cycle.

The possibilities of the design of the technical barrier system, the applicable materials, arrangements, the behaviour and role of the various filling and backfilling materials in guaranteeing long term safety, the technological terms of the implementation of the technical barrier system must be studied. The design and system of the insulation and sealing plugs intended for the closure of the disposal facility must be planned, the closure concept must be developed.

Mechanical, physical, chemical, thermal, microbiological and radiological processes affecting and changing the behaviour and the properties of the repository host rock as a result of the space use and waste disposal in the direct geological vicinity of the disposal facility must be determined. The possible methods of space use and cavitation filling must be worked out.

The current conditions and long term development of the farther geological environment of the disposal facility must be assessed. The geometric spread, mineral-lithological, hydrogeological and transport properties of the host formation, the geodynamic characteristics and expected surface development of the area must be determined in the framework of a geological research. The subsurface water flow system and its potential future changes must be assessed with numeric modelling for various climate scenarios. The processes of gas formation and gas transport must be analysed.

The natural environment of the disposal facility, the baseline condition, the environmental impacts expected as a result of the establishment and operation of the disposal facility, the impact areas, the condition changes must be described. The locations of the surface facilities and their geomorphological risks must be dealt with. Various scenarios must be worked out for the transport processes expected to take place in the biosphere after the closure of the disposal facility.

A concept related to the design (conditioning, containerisation) of the waste packages and to their delivery to the site must be worked out. Issues of the operational radiological safety, the exclusion of criticality, issues related to the registration and recoverability of the waste packages must be preliminarily studied, the requirements of the long term data retention, the expectations related to the monitoring and the institutional control must be worked out.

The models, software assessing the operational and long term radiological safety of the disposal facility, the methods and methodology of the safety assessments must be developed in compliance with the international recommendations. The experiences, research, development and demonstration activities of the more advanced foreigner waste disposal programmes must be studied, and the applicable solutions must be adapted.

8.4 Research & Development Tasks Related to Decommissioning

During the decommissioning of the nuclear facilities, several aspects demanding scientific foundation and detailed technological and economic planning must be applied. These include decommissioning operations involving the treatment of radioactively contaminated materials and thereby generating also radioactive wastes. Launching of a research project might be necessary in order to create a knowledge base (training system) by means of which the followings can be promoted:

- Optimisation of the radiation exposure of the specialists performing the operations: assessment of the possibilities of internal radiation exposure, minimisation of exposure, establishment of fast calculation and measurement methods to determine the contamination and the exposure; calculation, measurement of the dose fields, and methods of the application of protection materials.

- Preparation of remote controlled and manual operational procedures: design and testing of robotic, control and measuring equipment suitable for the decommissioning and disassembly tasks, means and methods of the on-site treatment and conditioning of the radioactive wastes, specific requirements of the disposal of the decommissioning wastes.
- Analysis of the specificities of accident prevention of the decommissioning operations: methodology of the drawing of accident prevention plans, selection criteria of devices applicable in accident prevention.
- Determination and minimisation of the potential environmental impacts.

The establishment of a demonstration facility, i.e. the construction of building where the above activities can be safely and cost-efficiently implemented would be very beneficial for the above tasks (particularly for the first two ones). The research & development programme related to the development of the decommissioning technology is included in Section 4.3.2 “National Priorities” of the National Smart Specialisation Strategy approved by the Government in December 2014.

In addition to the above topics, the development of special measuring equipment might be necessary for the determination of the activity concentration and the activity distribution of the decommissioned technological materials and contaminated concrete debris. With direct measurement in the case of gamma radiating radionuclides and with the so-called “scaling-factor” method in the case of other radionuclides, the equipment helps to decide easily and quickly if the specific material volume can be released or not. An automated system operating on the basis of a principle similar to the above measuring equipment must be developed for the qualification of the wall surfaces and the implementability of their release.

9 The End Points and Internal System of Correlations of the National Programme

The system of correlations of the activities covered by the national programme is presented in this section for the period designated by the completion of the decommissioning in relation to the currently operating four nuclear power plant blocks. The way the new nuclear power plant blocks can be integrated into the system was presented by the previous sections in detail. The following reference scenarios can be designated in connection with the individual facilities and activities.

In the case of the Budapest Research Reactor, shutdown in 2023 is taken into account as a reference case. The facility will be decommissioned after the interim period. The reference date of the shutdown of the Training Reactor taken into account in the national programme is 2027, which is followed by the interim period and the decommissioning until the final state to be achieved. Delivery of the spent fuel of the Budapest Research Reactor to Russia must be delayed until the shutdown of the Training Reactor, therefore all the spent - and possibly remaining fresh - fuels can be delivered out in one stage.

The four operating blocks of the Paks Nuclear Power Plant will be shut down between 2032 and 2037. The interim period providing the cooling of the spent fuel of the last campaign is followed by the 20 year safeguarding of the primary circuit, and then by the demolition of the reactors until the final state foreseen in the decommissioning plan.

The low and intermediate level waste of nuclear power plant origin will be finally disposed in the NRWDF. The disposal facility must be expanded in accordance with the operating and then the decommissioning waste volumes. Due to the delayed decommissioning strategy of the Paks Nuclear Power Plant, there will be a period during the operation of the disposal facility when only conservation is made, without waste delivery and disposal. Then the low and intermediate level wastes deriving from the demolition of the Paks Nuclear Power Plant will be disposed, followed by the decommissioning of the surface site of the NRWDF, the closure of the disposal facility and the active institutional control.

Radioactive wastes of institutional origin will be received by the RWTDF. The facility is suitable for the final disposal of short-lived low and intermediate level wastes, while wastes that may not be finally disposed in the surface disposal facility will be forwarded to the interim storage facility located at the site. The long-lived wastes the interim storage of which is provided by the RWTDF will be finally disposed in a deep geological repository to be established on the area of Hungary. Based on this, the RWTDF must be kept in operation at least until the time when the above wastes can be transferred to the deep geological repository. The demolition of the buildings and the closure of the disposal facility, which is also the beginning of the active institutional control, may be started subsequently.

The interim storage of the spent fuel generated during the operation of the Paks Nuclear Power Plant is implemented in the ISFS established in Paks. According to the reference scenario applied for the closing section of the nuclear fuel cycle, the spent fuel will be then directly disposed in a deep geological repository to be established in Hungary, which will be commissioned in 2064 according to the current plans. The same disposal facility will be used for the final disposal of high level and/or long-lived wastes generated during the operation and decommissioning of the Paks Nuclear Power Plant.

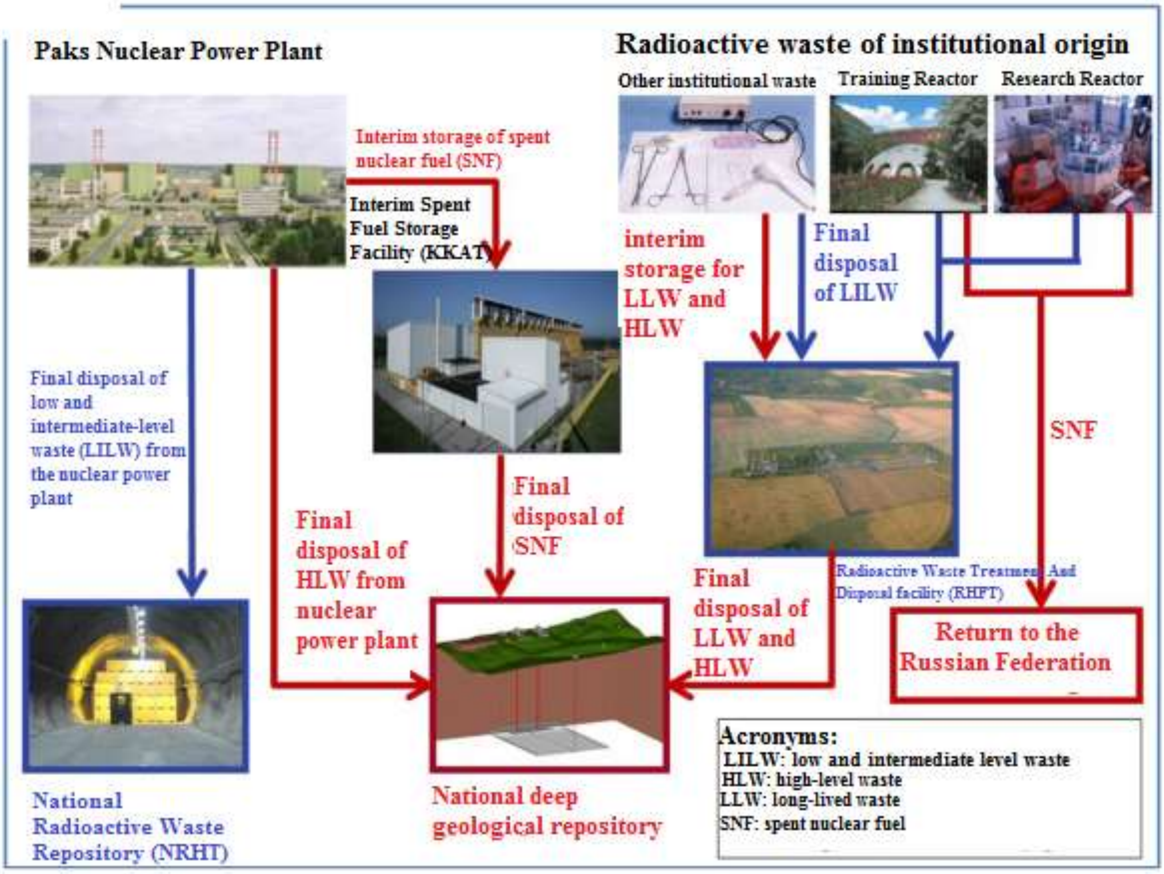


Figure 18: Logical scheme of the treatment of spent fuel and radioactive waste

Based on the reference scenarios currently used in Hungary, the above scheme of the treatment of spent fuel and radioactive wastes is illustrated by Figure 18, while its schedule by Figure 19.

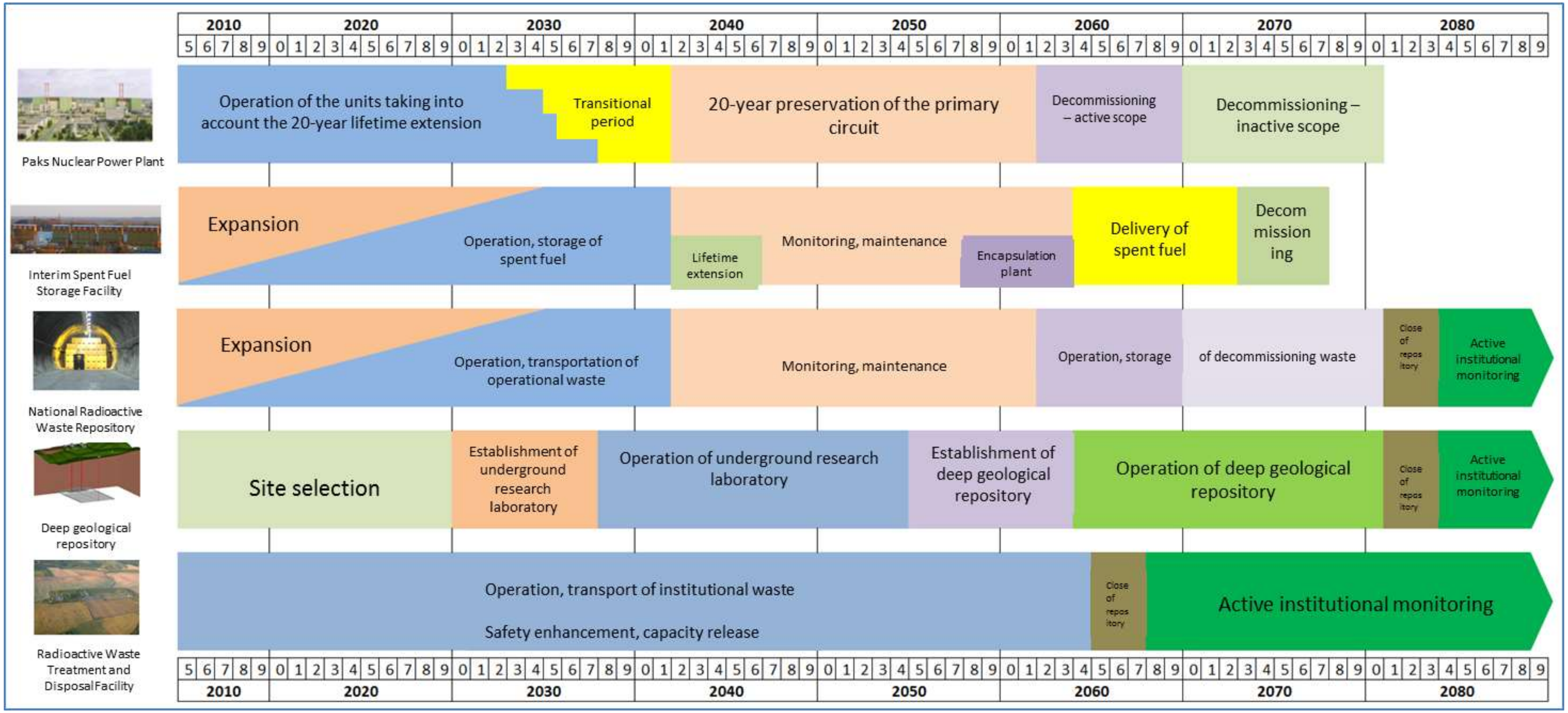


Figure 19: The schedule of activities related to the treatment of spent fuel and radioactive wastes in view of the currently operating four nuclear power plant blocks

10 Monitoring of the Advance

The previous chapters of the national programme presented the tasks related to the final disposal of the radioactive wastes, the interim storage of the spent fuel and the closing stage of the nuclear fuel cycle as well as the decommissioning. Since the national programme must be reviewed every five years - unless earlier review is justified by a significant change -, the major milestones expected in the next 5 years are presented in relation to the major programme elements in Table 5. The progress of the individual activities can be determined with reference to these milestones, which must be covered by the national report required by the Directive and to be drawn every three years for the European Commission.

Table 5: Key performance indexes to be used in the next five years for the evaluation of the progress of the individual activities

Facility/activity	Milestone	Objective to be achieved
Introduction of the category of very low level wastes	2018	A concept for the final disposal of very low level wastes must be worked out based on which the necessary modifications of the legislation can be introduced.
Closing stage of the nuclear fuel cycle	2020	A comparative safety, technical, economic review related to the final closure of the nuclear fuel cycle must be performed.
Treatment of radioactive wastes in the Paks Nuclear Power Plant	2017	The cementing technology used for the preparation of the compact package wastes must be commissioned.
RWTDF	2017	The terms of the continuation of the safety increasing programme must be provided, and then the retrieval of the radioactive wastes must be started.
NRWDF	2017	Storage chamber I-K2 must be commissioned, which will be suitable for the receipt of compact waste packages prepared by the Paks Nuclear Power Plant.
ISFS	2017	The establishment of Chambers 21-24 must be finished.
Selection of the depth disposal facility	2020	Surface research phase I must be closed, and based on its results, the plan of surface research phase II must be drawn.
Decommissioning of the Paks Nuclear Power Plant	2016	The decommissioning plan of the Paks Nuclear Power Plant must be reviewed and updated to the necessary extent.
Decommissioning of the Budapest Research Reactor	2020	The decommissioning plan of the Budapest Research Reactor must be reviewed and updated to the necessary extent.
Decommissioning of the Training Reactor	2019	The decommissioning plan of the Training Reactor must be reviewed and updated to the necessary extent.
Decommissioning of the ISFS	2016	The decommissioning plan of the ISFS must be reviewed and updated to the necessary extent.

11 Financing of the Activities

11.1 The Central Nuclear Financial Fund

Users of nuclear energy during the activities of which radioactive wastes or spent fuels are generated must bear the costs of their treatment, and also the decommissioning costs in the case of a nuclear facility.

Based on the requirements of the Nuclear Act, the Fund - as a separate state fund - finances the implementation of tasks related to the final disposal of radioactive waste as well as the to the interim storage of the spent fuel and the closure of the nuclear fuel cycle, and the decommissioning of the nuclear facility. The financial assets of the Fun may be used only for the financing of these activities.

The method of provision of the long term financial coverage necessary for the treatment of the radioactive waste and the spent fuel in the Paks Nuclear Power Plant and for the decommissioning of the facility, the specification of the obligation to settle payments into the Fund are detailed in Section 11.2.

In the case of nuclear facilities operated by the budget institutions - such as the Budapest Research Reactor and the Training Reactor - the costs related to the interim storage of the spent fuel, the closure of the nuclear fuel cycle as well as the decommissioning of the nuclear facility must be paid into the Fund at the time they arise, the source for which is provided by the central budget in the annual budget of the operating institution.

Payment obligations related to the final disposal of radioactive waste of institutional origin must be met at the time of delivery to the RWTDF in accordance with the Nuclear Act.

The financial assets of the Fund are separately recorded on a single treasury account, and are supported from the central budget in an amount calculated on the basis of the average money stock of the previous year with the mean prime rate of the central bank (interest service) to keep its value.

11.2 Medium- and Long-Term Financial Planning

Tasks related to the treatment of the radioactive wastes and spent fuel of the Paks Nuclear Power Plant and to the decommissioning of the facility are summarised in the so-called medium- and long-term plan approved by the competent minister and annually updated. This plan contains the costs arising in connection with the implementation of the above tasks, for the coverage of which the Paks Nuclear Power Plant must pay settle payments into the Fund in equal annual amounts until the end of its operating time. The payment obligation must be specified with the method of the net present value computation, which means, in fact, that the present value of future costs must equal the present value of the amount derived from stock of the Fund and additional payments of the Paks Nuclear Power Plant. The annual payment obligation of the Paks Nuclear Power Plant must be specified with the following formula.

$$F_0 + \sum_{i=0}^{n-1} \frac{B_i}{(1+d)^i} - \sum_{i=0}^{m-1} \frac{K_i}{(1+d)^i} = 0$$

Where: F_0: money accumulated in the Fund until the date of calculation
B_i: payment obligation of the Paks Nuclear Power Plant in year “i”
n: number of years of payment
K_i: cost demand of activities financed from the Fund in year “i”
m: number of years of payment
d: discount factor

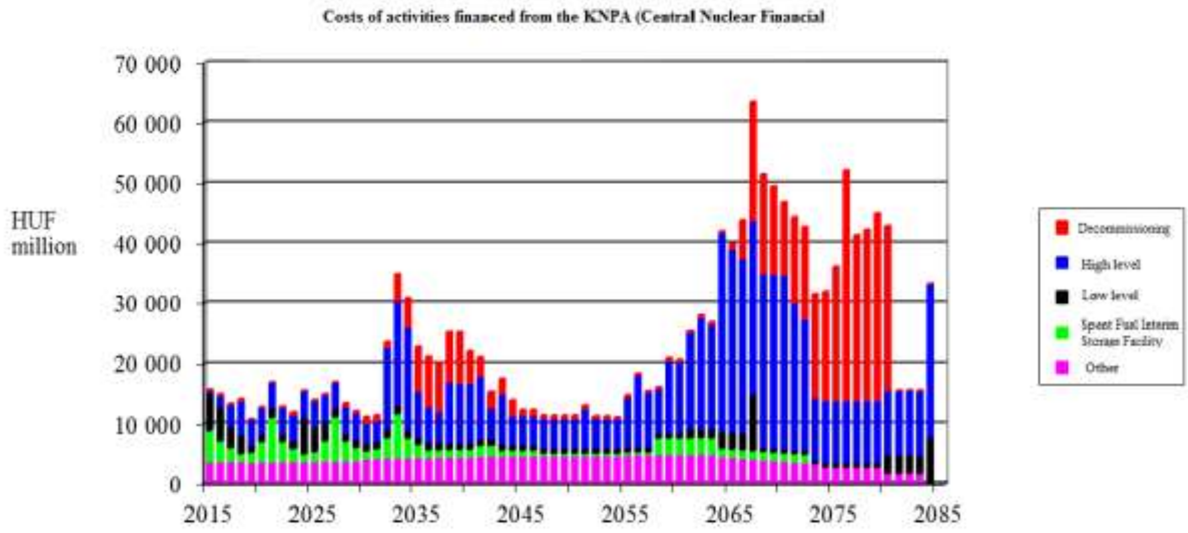
The central budget provides an interest service on the stock of the Fund in accordance with Section 11.1. Based on the applied methodology, the discount factor in the net present value computation is the “effective interest” content of the prime rate of the central bank, i.e. its part exceeding the inflation.

Table 6: The cost demand of the activities to be financed from the Fund at the base price of 2015

Activity	Cost demand (HUF million)
National Radioactive Waste Disposal Facility (NRWDF)	**78,799.1**
Establishment, expansion	20,976.7
Operation	30,521.8
Retention, conservation	7,241.6
Closure, institutional supervision	20,058.9
Disposal of high level wastes	**745,278.5**
Preparation	58,130.0
Establishment	293,568.1
Operation	326,164.2
Closure, institutional supervision	67,416.2
Interim Spent Fuel Storage Facility (ISFS)	**120,738.3**
Establishment, expansion	60,282.6
Renovation	519.6
Operation of ISFS	59,936.1
RWTDF of Püspökszilágy	**46,550.3**
Safety increase	2,267.1
Operation	30,496.8
Closure, institutional supervision	13,786.5
Decommissioning and demolition of the Paks Nuclear Power Plant and the ISFS	**386,669.7**
Other costs	**272,366.1**
Support by Local Governments	98,233.8
Fund manager	9,928.4
Surveillance fee	60,287.8
Operating cost of the PURAM	103,916.1
ALL TOGETHER:	**1,650,402.0**

Based on the budget estimate made in 2014 and presented in the 14th medium- and long-term plan, Table 6 presents the cost elements taken into account in the specification of the obligation of the Paks Nuclear Power Plant to pay into the Fund at the base price of 2015 without discounting. The computation was made in the national programme for the reference case and schedule presented in Chapter 9 - based on the extension of the operating time of the Paks Nuclear Power Plant with 20 years and on the direct disposal of the spent fuel - for a period until 2084 taken into account for the current four nuclear power plant blocks.

Figure 22: The future trend of costs of the National Program.



Based on the schedule of the cost demands of the activities financed from the Fund, using a discount factor of 2.5%, the present value of costs included in Table 6 is HUF 672,492 million. The amount of the stock of the Fund at the beginning of 2015 (HUF 246,376 million) and the present value of payments to be regularly settled by the Paks Nuclear Power Plant until the end of the operating time must equal this present value. This is how the costs related to the treatment of the radioactive waste and the spent fuel as well as to the decommissioning are paid by the licensee, in connection with which these costs have arisen. Amounts deposited by the Paks Nuclear Power Plant in the Fund to cover the implementation of tasks belonging to the scope of the national programme are integrated into the electricity price, and thereby the principle that this generation does not pass unreasonable challenges to the future generations is met.

11.3 Insertion of the New Nuclear Power Plant Blocks into the Financing System

The licensee of the new nuclear power plant blocks to be established at the site of Paks will settle the first payment into the Fund in the year following the commissioning of the fifth block. It was presented in the previous sections that the spent fuel generated in the new blocks and the treatment of the radioactive waste can be safely solved.

The preliminary analyses have shown that if the larger volume resulting from the six nuclear power plant blocks is taken into account in the treatment of the radioactive wastes and the spent fuel, then the specific cost of the radioactive waste treatment (related to either the waste volume or the generated electricity volume) will be much more favourable. This is a natural consequence of the fact that the fixed costs of the facilities intended for joint use (e.g. the NRWDF, the deep geological repository) available for the six blocks are shared not by four but by six blocks.

To summarise the above, we can state that the new blocks can be integrated into the financing system created for the treatment of the radioactive waste and spent fuel and for the decommissioning of the nuclear facilities, the obligation of the licensee to pay into the Fund can be specified in view of the current reference scenarios.

12 Provision of Transparency, Involvement of the Population into Decision-Making

A key issue of the use of the nuclear energy is the winning and keeping of the confidence and support of the population, which is particularly true for the treatment of the radioactive waste and the spent fuel and the activities related to the final disposal. The study of the international practice confirms the necessity of the involvement of the population with several examples; those national programmes can successfully advance where they are supported by the public opinion in partnership.

The national communications with the population is, in fact, based on cooperation with the control and information local government associations established in the vicinity of the planned or implemented facilities. This partnership cooperation was established in the beginning stage of the launching of the radioactive treatment programmes (for which an example is given in Section 12.1), and they still operate within the framework specified by the Nuclear Act. This allowed and still allows the successful advance of the programmes, the implementation and smooth operation of the facilities. The currently operating local government associations - the locations of which are presented by Figure 20 - are as follows:

- in relation to the RWTDF of Püspökszilágy: the Isotope Information Association (**IIA**), to which 5 settlements (Kisnémedi, Püspökszilágy, Váckisújfalu, Váchartyán, Őrbottyán) belong;
- in relation to the NRWDF in the region of Bátaapáti: the Social Control Information Association (**SCIA**), to which 7 settlements (Bátaapáti, Bátaszék, Cikó, Feked, Mórágy, Mőcsény, Véménd) belong;
- in relation to the site selection programme of the deep geological repository: the Western Mecsek Social Information and Resettlement Local Government Association (**WMSIRA**), to which 9 settlements (Bakonya, Boda, Kővágószőlős, Kővágótöttös, Hetvehely, Cserkút, Cserdi, Helesfa, Bükkösd) belong;

- in relation to the ISFS of Paks: the Social Control Information and Resettlement Association (**SCIRA**), to which 13 settlements (Kalocsa, Bátya, Dunaszentgyörgy, Dunaszentbenedek, Fadd, Foktő, Géderlak, Gerjen, Ordas, Paks, Pusztahencse, Tengelic, Uszód) belong.

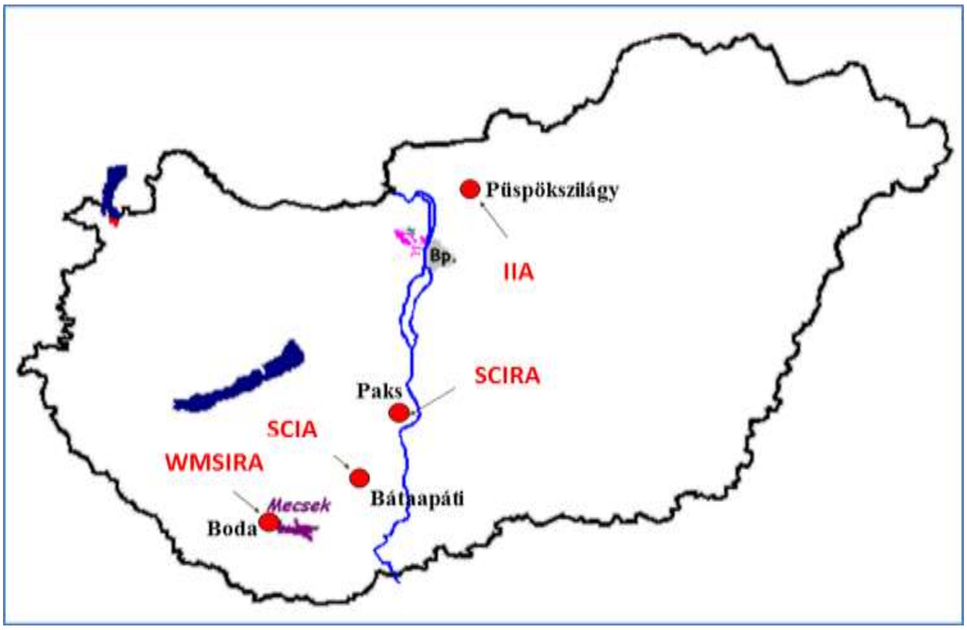


Figure 20: Control and information local government associations

The local government associations assist in the notification of the local population of information related to the facilities and activities on the one hand, and give feedbacks on the opinion of the region's inhabitants to the implementers of the programmes on the other hand. The associations operate websites to supply updated information, and notify the concerned population via regular newsletters and cable TV programmes. The control function of the associations is also very important. In its framework, groups of local inhabitants were set up which periodically control the facility operating in their vicinity for reliability.

Naturally, the local government associations are not an exclusive source of communications. The organisation designated by the Nuclear Act to treat the radioactive waste and the spent fuel - the PURAM - notifies the local inhabitants of the progress of the projects directly, via several channels. The list of key means of communications, which is not exhaustive:

- the locally operating visitors' centre, showroom, information park;
- information events arranged at the settlements (e.g. SCIA Day, Orientation Day);
- publications presenting the activities;
- the company's website (www.rhk.hu); and
- open days organised in the facilities.

The opinions of the inhabitants living in the region in question are assessed via polls every two years, which is an important feedback from the aspect of communications and, in general, the performance of the facility related activity. The latest polls were made in 2011 and 2013, the results of which are illustrated by Figures 21 and 22 in relation to the NRWDF of Bátaapáti and to the research made to select the location of the deep geological repository.

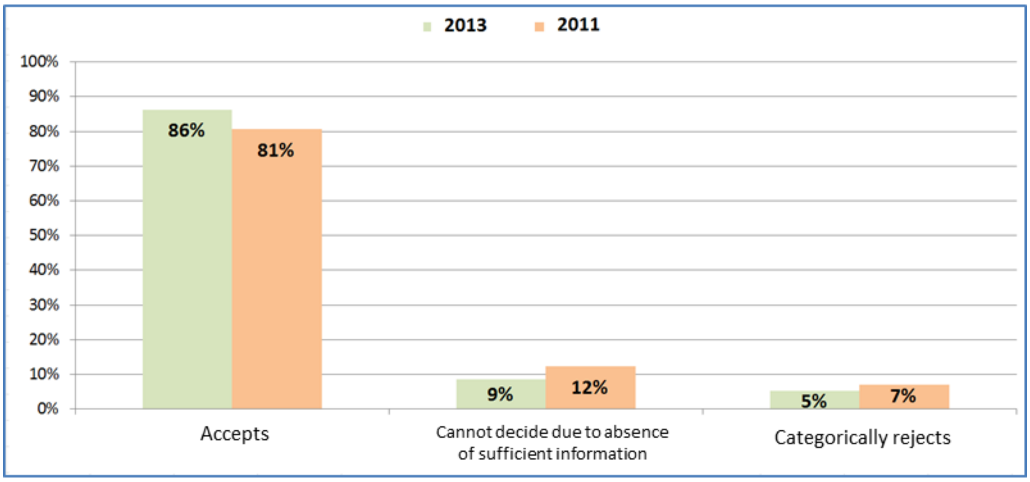


Figure 21: The acceptance of the location of the NRWDF of Bátaapáti

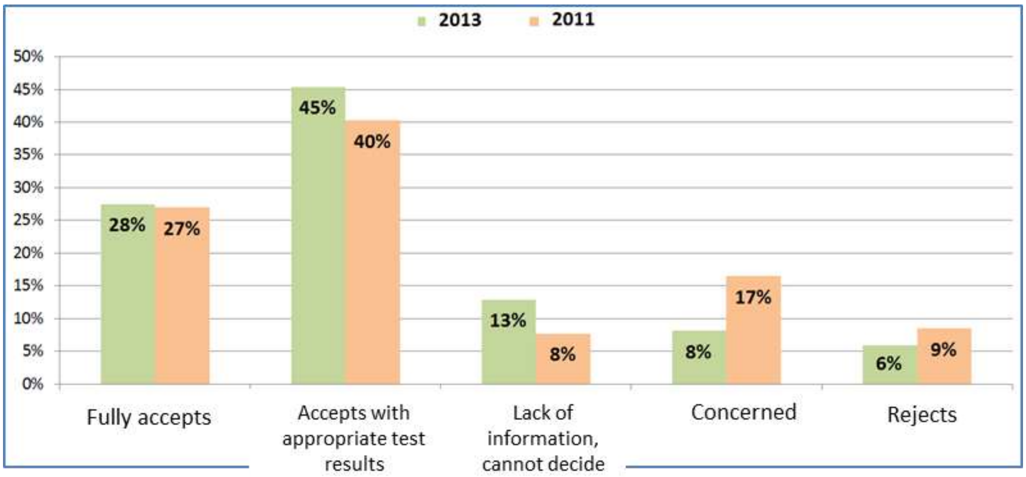


Figure 22: Distribution of answers given to question "What do you feel in connection with the disposal facility planned in the region?" in the research region of the deep geological repository

The results of the survey well indicate that, in general, the location of the NRWDF facility and the choice of the site in the region of Western Mecsek are accepted by the majority of the local inhabitants, and a slight increase of the support has been shown since 2011.

Simultaneously with the implementation of the notification policy based on the principles of publicity and transparency and covering also special issues, the public opinion must be also involved in decision-making. The population can be involved in decision-making belonging to the scope of the environmental and nuclear energy surveillance bodies in connection with the activities covered by the national programme via public hearing within the framework of the legislation.

The use of the above principles - related to the notification of the inhabitants and their involvement in the decision-making process - in practice is presented with the example of the NRWDF in section 12.1.

12.1 Involvement of the Population in the Selection and Establishment of the Site of the NRWDF

A combined site selection process was implemented in the framework of the National Project launched for the disposal of low and intermediate level waste of nuclear power plant origin. First, 128 sites were designated for surface location and 193 sites for subsurface location on the basis of the geological characteristics. The public opinion was involved in the process of the selection of the sites by asking the opinions of all local governments receiving the potential sites if they supported the researches in their regions. Ca. 10% of the local government responded positively, therefore the number of the potential target areas reduced to several dozens. Among the four sites remaining in the last phase of the selection of sites as a result of the detailed surface geological researches, Bátaapáti was chosen, and therefore the detailed surface exploration of the granite formation receiving the disposal facility was started there.

The local government association of the region, the SCIA, was created in 1997 to provide updated information for the population on the disposal of the low and intermediate level radioactive waste. When the suitability of the site of Bátaapáti was confirmed by the detailed explorations, the municipal council of Bátaapáti initiated a poll in the settlement. With a high participation rate (75%), nearly 90.7% of the voters agreed with the construction of a low and intermediate level waste disposal facility in Bátaapáti.

The two-stage environmental licensing of the disposal facility started in 2005. Based on the clear summary of the environmental impact study documentation submitted in the second licensing step, the regionally competent environmental authority held a public hearing in Bátaapáti on 29 March 2007. In the framework of the public hearing, all parties concerned could make remarks on the potential environmental impacts of the disposal facility, which were studied by the environmental authority on the merit. As a result of the procedure, the Energy Club submitted an appeal against the environmental licence of first instance. The decision of first instance was approved by the National Chief Inspectorate for the Environment, Nature Conservation and Water acting in the second instance in its decision of 5 October 2007, finalising the topographical numbers concerned.

After the selection of the site, the notification of the population continued via several channels. These include, in particular, the annually arranged SCIA Day, the SCIA Newspaper, the SCIA Magazine video news, the periodically issued information and awareness raising publications as well as the websites of the SCIA and the PURAM. In addition to the notification, the SCIA founded the public control group in 2007, which has been controlling the activity of the PURAM since the arrival of the first radioactive waste containing barrel at the NRWDF. A total of 18 heads from 7 member settlements of the association take part in the work of the control book. This social control significantly contributes to the credible notification and the increase of the confidence of the inhabitants of the region.

Annex 1

Characteristics and volumes of fuel types applied in the Paks Nuclear Power Plant

Work assembly	**First generation**					**Second generation**	
Factor type ID	116	124	136	138	138205	142013	147010
Profiled	no	no	no	yes	yes	yes	yes
Number of Gd-os rods [pcs]	0	0	0	0	0	3	6
Average enrichment [%]	1.6	2.4	3.6	3.82	3.82	4.2	4.7
Uranium mass [kg]	120.2	120.2	120.2	120.2	120.2	126.3	126.3
Rod pitch [mm]	1.22	1.22	1.22	1.22	1.23	1.23	1.23
Maximum operating time [years]	4	4	4	5	5	5	5
Max. Burnability [Mwnap/kgU]	49	49	49	49	50.5	54	58
Average real burn [Mwnap/kgU]	10.66	26.17	33.82	37.75	40.67	45.19	-

SZBV assembly	**First generation**				**Second generation**	
Factor type ID	216	224	236	238207	242014	247012
Profiled	no	no	no	Yes	Yes	Yes
Number of Gd-os rods [pcs]	0	0	0	0	3	6
Average enrichment [%]	1.6	2.4	3.6	3.82	4.2	4.7
Uranium mass [kg]	112.5	112.5	112.5	112.5	120.3	120.3
Rod pitch [mm]	1.22	1.22	1.22	1.23	1.23	1.23
Operating time [year]	4	4	4	4	5	5
Max. burnability [Mwnap/kgU]	49	49	49	50.5	54	58
Average real burn [Mwnap/kgU]	9.97	26.76	32.43	37.27	45.5	-

Annex 1: Characteristics and volumes of fuel types applied in the Paks Nuclear Power Plant

Work assembly [pcs]		**Disposal object**					
Factor type ID		Fresh fuel storage facility	Reactor	Retention pool	Russia	ISFS	Total
First generation	116	12	0	34	440	114	**600**
	124	24	0	37	478	763	**1302**
	136	0	0	26	1179	4672	**5877**
	138	0	12	163	1	1361	**1537**
	138205	0	246	1158	0	234	**1638**
Second generation	142013	436	978	84	0	0	**1498**
	147010	0	12	0	0	0	**12**
Total:		**472**	**1248**	**1502**	**2098**	**7144**	**12464**
Follower assembly [pcs]		**Disposal object**					
Factor type ID		Fresh fuel storage facility	Reactor	Retention pool	Russia	ISFS	Total
First generation	216	5	0	13	53	18	**89**
	224	7	0	2	196	451	**656**
	236	0	0	34	18	434	**486**
	238	0	0	0	0	0	**0**
	238207	0	22	164	0	30	**216**
Second generation	242014	45	126	18	1	0	**190**
	247012	0	0	0	0	0	**0**
Total:		**57**	**148**	**231**	**268**	**933**	**1637**

Total fuel assemblies [pcs]		**Disposal object**					
Type	Enrich-ment	Fresh fuel storage facility	Reactor	Retention pool	Russia	ISFS	Total
First generation	1.6	17	0	47	493	132	**689**
	2.4	31	0	39	674	1214	**1958**
	3.6	0	0	60	1197	5106	**6363**
	3.82	0	12	163	1	1361	**1537**
	3,82n*	0	268	1322	0	264	**1854**
Second generation	4,20n*	481	1104	102	1	0	**1688**
	4,70n*	0	12	0	0	0	**12**
Total:		**529**	**1396**	**1733**	**2366**	**8077**	**14101**
Absorber [pcs]		**Disposal object**					
		Fresh fuel storage facility	Reactor	Retention pool	HLW well	MPC	Total
Total:		**51**	**148**	**108**	**528**	**2**	**837**

*: letter “n” indicates assemblies with increased pitches

Annex 2

List of international agreements signed by Hungary in connection with the handling of spent fuel and radioactive wastes.

[1] Agreement between the Revolutionary Worker-Peasant Government of the Republic of Hungary and the Government of the Federation of the Soviet Socialist Republics on cooperation in the establishment of a nuclear power plant in the Republic of Hungary (28 December 1966).

  [1a] Government Decree 244/2004 of 25 August 2004 on the announcement of the protocol signed between the Government of the Republic of Hungary and the Government of the Russian Federation on the terms of the return of the radiated spent fuels of Russian make (spent fuel) from the Paks Nuclear Power Plant to the Russian Federation

[2] Government Decree 204/2008 of 19 August 2008 on the announcement of an agreement on cooperation between the Government of the Russian Federation and the Government of the Republic of Hungary in connection with the return of the spent fuels of the research reactor to the Russian Federation

  [2a] Government Decree 179/2008 of 5 July 2008 on the announcement of an agreement between the Government of the Republic of Hungary and the Government of the United States of America on the support and financing of the return of the spent fuels of the research reactor into the Russian Federation

[3] Act II of 2014 on the announcement of an agreement on the cooperation between the Government of Hungary and the Government of the Russian Federation on the use of nuclear energy for peaceful purposes