

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Public summary

25 June 2026

PAKS NUCLEAR POWER PLANT
SUBSEQUENT SERVICE LIFE EXTENSION



Paks NPP

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1. Introduction

1.1. Background

The Paks Nuclear Power Plant (Paks NPP) is a key component of the Hungarian electricity system with generation of electric power as its primary function. The NPP, operated by MVM Paksi Atomerőmű Zrt. consists of four VVER-440/V-213 reactor units, which were commissioned between 1982 and 1987. The Paks NPP currently has a nominal electrical capacity of 2,026.6 MW. With an annual output of nearly 16 GWh, the plant plays a key role in Hungary's electricity generation, accounting for more than 40% of the total. Since the Paks NPP commenced operations, numerous safety-improvement measures and modernization programs have been implemented. In accordance with the European Union's climate policy goals, the Union aims to achieve climate neutrality by 2050, a goal that all member states have reaffirmed and expressed firm commitment to. Nuclear power and renewable energy sources can produce electricity without carbon dioxide emissions. The Paks NPP thus plays a decisive role in achieving the climate neutrality targets of Hungary.

In line with international trends, MVM Paksi Atomerőmű Zrt. began exploring the possibility of extending the plant's original 30-year design service life in the early 2000s with the involvement of technical, scientific and economic institutions. Based on the auspicious results of the detailed feasibility studies conducted, in 2003 a decision was made to extend the NPP's service life initially by 20 years. As a result of the operational and maintenance practices employed at the NPP, the robust design of the structures and system components, as well as the reconstructions and safety-upgrading measures implemented, the condition of the plant permitted the safe operation beyond 30 years. As one of the first steps in the licensing process, which comprises environmental, nuclear and electric power industry licensing procedures, an environmental impact assessment was conducted.

The environmental impact assessment prepared in 2006 regarding the first service life extension for the NPP concluded that the extension was feasible from the environmental perspective. The South-Transdanubian Environmental, Nature Conservation and Water Management Inspectorate issued the environmental license to MVM Paksi Atomerőmű Zrt. for the operation of the NPP's units for 20 years beyond the original 30-year design service life in October 2006. The prevalent environmental license was issued on a unit-by-unit basis, with validity expiring between 2032 and 2037, corresponding to the additional 20-year service life of each unit.

As early as 2013, during the implementation of the initial service life extension project, the NPP's experts began exploring the possibility of a subsequent service life extension (SSLE) beyond the approved 50-year (30+20) service life. As part of MVM Paksi Atomerőmű Zrt.'s corporate strategy, an investigation into the possibility of a SSLE was launched in 2019, followed by a preliminary analysis in 2020 regarding legal, technical and economic feasibility. Although the economic and climate policy benefits of a SSLE were evident and several countries have already been considering extending the service life of existing NPPs from 60 to 80 years, or even from 80 to 100 years – due to changes in the schedule for the Paks II NPP originally planned – the decision to launch the Paks project was only made later.

Preparations for a NPP's service life extension takes nearly 10 years. Considering that the service life of Unit 1 expires in 2032, in the summer of 2022, the Government of Hungary decided to commence preparations for the subsequent extension of the service life of Paks NPP.

In September 2022, MVM Paksi Atomerőmű Zrt. launched its Priority Project for SSLE. The tasks to be carried out under the project included conducting an environmental impact assessment, comprising the implementation of specialized investigation programs that form the basis for preparing the environmental impact assessment, as well as conducting the environmental licensing procedure. The scope of the project also includes technical analysis tasks that are aimed at the detailed assessment of the condition of the NPP's structures, building components and equipment; reviewing the current aging management programs designed to detect aging processes in a timely manner, to effectively prevent and address the effects of aging; and, if necessary, the development of new programs. Based on the results of the studies to be conducted, the project will be the framework for the implementation program for the SSLE, the

license applications required for the nuclear regulatory licensing procedures and the preparation of the supporting documentation also.

The service life of the Paks NPP as a facility is determined by those structures and system components that cannot be replaced or refurbished or for which the associated costs and downtime would be so high that it would not be reasonable from a technical and economic point of view. Based on material testing, analysis and maintenance figures, none of the equipment, most critical to nuclear safety, is expected to become inoperable, or incur excessive costs due to the intended ageing as part of the plant operations during the plant's extended service over 70 (30+20+20) years. The safe operation of replaceable and refurbishable system components can be ensured during the extended service period through the implementation of planned aging management and reconstruction programs. In the course of the assessments, changes over the past 70 years in external and internal conditions, as well as in technical and scientific knowledge were also taken into account.

Considering international practices regarding the extension of service life of NPPs, the assessments of technical and environmental conditions of the continued operation of the Paks NPP calculate with a 20-year extension of the service life, resulting in a total service lifetime of 70 years.

Under current legislation, prior approval in principle from the National Assembly is mandatory for the construction of a new NPP but not required for the service life extension of an existing nuclear power units. Nevertheless, the National Assembly was properly informed of the commencement of preparations yet for the first service life extension of the Paks NPP. The Government has, therefore, decided to inform the National Assembly prior to the commencement of activities related to the subsequent extension of the service life of the Paks NPP.

The National Assembly, by its Resolution 56/2022. (XII. 8.) OGY, regarding the subsequent extension of the service life of the Paks NPP units, accepted and acknowledged the SSLE of the NPP which is in line with the country's goals for energy independence, climate protection and security of supplies.

Pursuant to Article 41 of Chapter 4 of the Euratom Treaty concerning investments, the service life extension project is subject to notification to the European Commission. Following consultations involving the Hungarian Atomic Energy Authority (HAEA) and the Ministry of Energy, a document presenting the project was sent on October 26, 2023 to the European Commission's Directorate-General for Energy, Unit ENER D.2 – Nuclear Energy, Nuclear Waste and Decommissioning. This marked the official notification to the European Commission regarding the SSLE of the Paks NPP. In January 2025, the Commission raised additional questions regarding the project, to which responses were submitted on April 9, 2025. The procedure will conclude with the issue of the Commission's final standpoint.

Pursuant to Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and the integrated environmental licensing procedures, the extension of a NPP's service life is an activity subject to an environmental impact assessment, which may be carried out only upon possession of an environmental license issued by the environmental protection authority. The applicant must present the results of the environmental impact assessment in an Environmental Impact Assessment. For the subsequent extension of the service life of the Paks NPP, an environmental license issued to MVM Paks Atomerőmű Zrt. is required, based upon the environmental impact assessment procedure conducted by the Baranya County Government Office (BCGO), as the competent environmental protection authority.

In the event of a subsequent extension of the NPP's service life, the legislation provides the applicant with the opportunity to conduct a so-called preliminary consultation prior to the environmental licensing procedure in order to obtain the opinions of the environmental protection authority and the relevant administrative bodies, as well as to get insight into public opinion. In accordance with the Government Decree 148/1999. (X. 13.) issued on the promulgation of the Convention on Environmental Impact Assessment in a Transboundary Context, signed in Espoo (Finland) on February 26, 1991, the public concerned shall also include the citizens of the countries notified during the preliminary consultations.

On 24th September 2024, the MVM Paksi Atomerőmű Zrt. initiated a preliminary consultation with the BCGO regarding the planned extension of the service life of Units 1-4 of the Paks NPP by an additional 20 years, submitting the document (Preliminary Consultation Document) in line with the content requirements set forth in Annex 4 of Government Decree 314/2005. (XII. 25.). The purpose of requesting the preliminary consultation was to ensure that the environmental impact assessment could be prepared taking into account the opinions of the environmental protection authority, the administrative bodies involved and perceptions of the public.

In its opinion concluding the preliminary consultation, issued on 24th October 2024, under file number 383-100/2024, the BCGO determined no reasons to exclude environmental licensing have arisen in connection with the subsequent extension of the NPP's service life. In its opinion, the environmental authority stated that, pursuant to legal requirements, the extension of the NPP's service life is an activity subject to an environmental impact assessment, which may be initiated and continued only upon possession of an environmental license. The application for the environmental impact assessment procedure must include an environmental impact assessment prepared in accordance with Annexes 6 and 7 of Government Decree 314/2005. (XII. 25.), taking into account the requirements set forth in the opinion of the Government Office concluding the preliminary consultation.

Given that the NPP is listed in Appendix I of the Espoo Convention, promulgated by Government Decree 148/1999. (X. 13.) among activities expected to cause significant transboundary environmental impacts – in accordance with the provisions of the Government Decree 314/2005. (XII. 25.) on the international environmental impact assessment procedure – foreign parties presumed to be interested were notified in order to establish opportunity for consultation. Maintaining contact with foreign interested parties is the responsibility of the ministry responsible for environmental protection.

The BCGO duly informed the competent Ministry of Energy of the commencement of the preliminary consultation, thereby providing foreign interested parties with the opportunity to participate in the preliminary consultation procedure. On 30th October 2024, the Ministry of Energy – taking into account the countries notified during the international environmental impact assessment procedure conducted for the Paks II NPP – notified 31 foreign parties (the neighbouring countries of Hungary, all EU member states, as well as the United Kingdom, Norway and Switzerland) in a circle extensively wider than the neighbouring countries of Hungary and independent of the limited potential transboundary impacts. Comments were received from the notified countries by 22nd January 2025, a total of 8 countries provided feedback. Austria, Latvia, Romania and Croatia indicated their preliminary intention to participate in the environmental impact assessment procedure, while Finland, Poland and the Czech Republic requested information on the results of the environmental impact assessment.

To carry out tasks related to the environmental licensing process for the SSLE, an independent project organization was established under the supervision of the environmental licensing working group operating within the framework of the SSLE Priority Project of the Paks NPP. This organization was managed by MVM ERBE Energetika Mérnökiroda Zrt. as the general contractor, with the involvement of the energy engineering offices of AFRY SOM System Kft. and AFRY ERŐTERV Zrt. To conduct the studies and analyses pertaining to specific areas of the environmental impact assessment professional organizations and scientific institutions with appropriate credentials were engaged. MVM Paksi Atomerőmű Zrt. established an Environmental Protection Expert Committee to oversee tasks related to environmental protection, whose members are recognized Hungarian scientific experts in the relevant fields.

This document is the public summary of the Environmental Impact Assessment Report (EIAR), which forms the basis for the environmental licensing of the SSLE of the Paks NPP and presents the results of the environmental impact assessment conducted.

The summary was prepared by AFRY ERŐTERV Zrt. in collaboration with MVM ERBE Zrt. and AFRY SOM System Kft., using the findings of the professional organizations having participated in the environmental impact assessment.

1.2. Definition of the planned activity

The planned activity involves extending the service life, its electricity generation activities of the Paks NPP – operating four VVER-440/213-type light water moderated pressurized water reactors – with an additional 20 years. The extension of the NPP's service life falls under point 31 of Annex 1 to Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and integrated environmental licensing procedure (*"Nuclear power plant, nuclear reactor and extension of the service life of a nuclear power plant or nuclear reactor"* – without size restrictions), i.e., it is an activity subject to an environmental impact assessment, for which an environmental license is required to commence.

The location of the activity is Hungary, Tolna County, the administrative area of the city of Paks (7030 Paks, lot no.: 8803/17), the existing site of the Paks NPP.

The planned subsequent extension of the service life applies to all four units of the NPP, meant per unit, taking into account the commissioning dates of the individual units. The planned start date of the activity is the expiration of the currently valid environmental license No. 391-18/2017 in force – specified for each unit according to *Table 1.2-1*. The duration of the SSLE for each unit, according to the intention of MVM Paks Atomerőmű Zrt., will last until the end of the final year of the extended service life of the given unit.

Table 1.2-1. Planned duration of the SSLE

NPP unit / system	Date of commissioning	End of the 50-year service life / beginning of the additional 20-year extended service life	End of the planned 20-year extended service life
Unit 1	14.12.1982.	14.12.2032.	31.12.2052.
Unit 2	26.08.1984.	26.08.2034.	31.12.2054.
Unit 3	15.09.1986.	15.09.2036.	31.12.2056.
Unit 4	09.08.1987.	09.08.2037.	31.12.2057.
Common systems		09.08.2037.	31.12.2057.

The nominal electrical output of Units 1-4 at the Paks NPP is 508.6, 506.0, 506.0 and 506.0 MW, respectively and the facility's total rated electrical output is 2,026.6 MW. The operation of the NPP during the extended service life period is planned as a baseload plant with continuous and nearly constant load; unit shutdowns will occur only for periodic maintenance in a planned and scheduled manner.

The environmental impact assessment for the subsequent extension of the NPP's service life applies to all four units of the plant, including the preparatory activities planned for the implementation of the service life extension. The assessments presented were conducted for the operation of all four-units of the NPP.

The scenario considered and assessed, involves exclusively the subsequent extension of the service life of the existing NPP at the existing site and using existing technology; there are no other site, technological or other alternatives in this case. In addition to the implementation of a subsequent extension of the NPP's service life, the only alternative permitted by law at the end of the currently authorized 50-year service life is the shutdown of the NPP units without the subsequent extension of the service life, the termination of electricity generation activities.

1.3. Purpose and justification of the planned activity

The purpose of the planned activity is to maintain the commercial generation of electricity currently carried out by MVM Paks Atomerőmű Zrt. through the operation of the Paks NPP by extending the operation of its existing four reactor units for an additional 20 years. Over the last decade (between 2015 and 2024), the Paks NPP generated between 15.7 and 16.3 TWh of electricity annually while maintaining a high-capacity factor. As a result, the plant has provided more than 40% of Hungary's domestic electricity generation, reaching nearly 48% in recent years.

The safe, affordable, and environmentally friendly electricity production of the Paks NPP has supplied a significant share of Hungary's electricity demand for more than four decades.

Consequently, the planned lifetime extension of the NPP supports Hungary's long-term objectives related to energy independence, climate protection, and security of supply. The Government's decision to initiate preparations for the SSLE project was justified by recent developments in international energy markets, electricity prices and demand, growing energy security risks.

The principal reasons for the planned lifetime extension of the Paks NPP include achieving climate policy objectives, meeting future electricity demand, ensuring security of supply, improving economic and cost efficiency, and reducing import dependency.

Climate policy framework and achievement of decarbonisation objectives

The environmental impact of technologically advanced societies is significant, and mitigating, or halting global warming is arguably one of the greatest challenges of our time. Under the climate policy objectives set forth in the Paris Agreement on Climate Change, the European Union aims to achieve climate neutrality by 2050. All EU Member States, including Hungary, signed and ratified the Paris Agreement, which entered into force in 2016. To fulfil these commitments, Hungary's Act XLIV of 2020 on Climate Protection established the objective of achieving full climate neutrality by 2050, meaning that the remaining domestic greenhouse gas emissions and removals will be brought into balance by that date.

The European Union remains dependent on external suppliers for natural gas. Therefore, future energy policy priorities focus on the production of carbon-neutral, affordable, and highly secure electricity, a role for which NPPs are particularly well suited. In Hungary, this objective can be achieved through the SSLE of the four operating units of the Paks NPP and the commissioning of the two new units of the Paks II NPP.

The revised 2024 version of Hungary's National Energy and Climate Plan (NECP) also assumes the SSLE of the Paks NPP. The document states that Hungary's objective is for the majority of domestic electricity generation to originate from two sources: nuclear energy and renewable energy. The latter primarily represented by solar power in line with Hungary's natural conditions. These technologies are not mutually exclusive, or competing alternatives. Rather, they complement and support one another, and both are considered clean energy sources. Nearly half of Hungary's electricity generation is currently provided by carbon-neutral nuclear energy. The planned SSLE of the Paks NPP and the commissioning of Paks II NPP will enable this proportion to be maintained in the long term.

The SSLE project is therefore fully aligned with Hungary's NECP, providing essential support for achieving the country's 2050 climate-neutrality targets.

The European Union's "Fit for 55" package and Hungary's legally established policy objectives require a radical reduction in greenhouse gas emissions and the achievement of net-zero greenhouse gas emissions by 2050. However, the revised 2024 NECP also makes it clear that the decarbonisation of Hungary's electricity sector cannot rely exclusively on weather-dependent renewable energy sources, as these alone cannot ensure security of supply due to their intermittent availability and generation profiles.

The exceptionally rapid growth of domestic photovoltaic capacity (which exceeded 8,000 MW by the summer of 2026 and is projected by the NECP to reach 12,000 MW by 2030) creates a structural asymmetry within the electricity system. Solar generation is inherently weather-dependent and cyclical, with minimal or zero availability during nighttime hours and during winter peak-demand periods.

In contrast, the Paks NPP continuously generates clean, carbon-free electricity with a capacity factor exceeding 90%. If the existing Paks units were to be shut down between 2032 and 2037, the approximately 16 TWh of annual electricity production loss, would have to be replaced – despite the commissioning of Paks II NPP – primarily through fossil-fuel-based generation, especially natural gas-fired power plants, or through increased electricity imports. Such a scenario would counteract decarbonisation objectives and would substantially increase the sector's carbon dioxide emissions.

It is important to emphasize that during the evening and nighttime hours, as well as during late autumn and winter periods when the Hungarian electricity system requires imports, neighbouring countries experience similar limitations in the availability of weather-dependent renewable resources. Typically, solar and wind conditions are comparable across the region, meaning that when solar generation is unavailable in Hungary, it is generally unavailable in neighbouring countries as well. Furthermore, a substantial share of the coal-fired generation capacity currently operating in neighbouring countries, which presently plays an important role in regional electricity supply, including exports to Hungary, is expected to be phased out. Consequently, from the mid-2030s onwards, these fossil-fuel-based sources can no longer be assumed to remain available. For this reason, it is of critical importance that the approximately 16 TWh of annual carbon-neutral baseload electricity that the Paks SSLE project seeks to secure for an additional 20 years remains available.

The achievement of climate policy objectives and security-of-supply objectives can therefore be linked through, among other measures, the Paks SSLE project, enabling their simultaneous realization.

Future electricity demand and security of supply

Both national and global trends indicate substantial growth in electricity demand. In recent years, Hungary's peak system loads have repeatedly reached new record levels, exceeding 8,000 MW, while the factors driving future demand growth are considerably stronger than those contributing to demand reduction. The principal drivers of growth include:

- Industrial electrification and high-tech manufacturing: Automotive manufacturing facilities already established or under development in Hungary, the associated large-scale battery manufacturing industry, and the growing number of data centres driven by digitalisation all require substantial, continuous, and reliable baseload electricity generation. If industrial facilities could operate only when the sun is shining and/or the wind is blowing, neither economically efficient operation nor effective workforce utilization would be possible.
- Electrification of transport: The increasing deployment of electric vehicles (passenger cars and buses), together with the expansion of urban rail-based transport systems (metro, tram, trolleybus) and long-distance railway transport, will generate significant additional electricity demand.
- Electrification of heating: A quiet revolution is taking place in residential and industrial heating and cooling systems, with an increasing number of buildings relying on heat pumps. These locally emission-free and highly controllable technologies play a vital role in reducing imported natural gas consumption and urban air pollution. As a result, they contribute not only to energy and climate policy objectives, but also to improved comfort and air quality. While the replacement of gas-based heating systems with heat pumps reduces natural gas consumption, it simultaneously increases electricity demand, particularly during periods when solar energy availability is limited. Moreover, the increasing frequency of summer heatwaves is driving wider adoption of air conditioning and building cooling systems, further increasing electricity demand. In this case, appropriate temporal coordination may allow solar generation to contribute effectively to meeting these needs.
- Economic growth in Hungary: The continued development of Hungary's economy itself is expected to increase electricity demand, as observed in other developed countries. A clear trend is the electrification of industrial processes that have traditionally relied on fossil fuels. As a result, electricity is becoming increasingly important within the overall energy supply mix.

An important aspect is that electricity markets are governed not only by energy policy and economic considerations, but also by the laws of physics, which in certain situations take precedence. It is not possible to base a country's secure electricity supply entirely on weather-dependent renewable energy sources, since the stability of the electricity system also requires controllable, synchronously operated power plants with rotating masses. Maintaining the existing Paks units is a key prerequisite for physical system balance, as the rotating mass of the Paks

turbines provides the electricity grid with physical characteristics that enable system control and ensure the conditions required for stability.

According to the forecast in the updated 2024 version of the NECP, Hungary's gross domestic electricity demand may increase from the current approximately 46-47 TWh to 53 TWh by 2030, to 68-72 TWh by 2040, and potentially to as much as 89-103 TWh by 2050. In this context, the existing Paks units, with their total capacity of 2,000 MW, annual generation of nearly 16 TWh, and system-stabilising and system-control functions, will remain an indispensable pillar of the Hungarian electricity system.

Economic justification and cost efficiency

NPPs must remain competitive in the electricity market. The economic advantages of the SSLE project can be summarised as follows:

- Exceptionally low specific investment cost: Extending the lifetime of an operating NPP – even including the necessary major refurbishments and equipment replacements – represents only a fraction, approximately 10-25%, of the cost of constructing an entirely new nuclear capacity as a greenfield investment. Since the initial capital investment has already been fully depreciated in financial terms, the generation cost of the electricity produced will be extremely low, contributing to keeping household electricity prices low and maintaining industrial competitiveness. In addition, the time required for the preparatory works associated with the SSLE is also only a fraction of that required for a new NPP investment.
- Minimisation of electricity-system-level costs: If an attempt were made to replace the existing 2,000 MW capacity with renewables and grid-scale battery energy storage systems, this would not be technically feasible at the current level of technological development. It would require such extensive transformation of the electricity grid and investment in balancing capacity, that the costs would exceed the cost of the Paks SSLE project by orders of magnitude. Replacement with natural gas-fired power plants would of course be technically possible, but it would increase dependence on imported natural gas, significantly raise electricity prices, and increase carbon dioxide emissions from the country's energy sector. In addition, the Paks NPP makes use of the already existing, robust transmission-grid connections.
- Marginal cost of operation: A further significant economic advantage of the additional lifetime extension is that 2,000 MW of capacity will remain in Hungary's electricity system with low variable costs, largely consisting of fuel costs associated with operation, and with no direct dependence on natural gas procurement prices. This substantially helps reduce the impact of price fluctuations observed on international natural gas and electricity markets on the cost of domestic electricity supply, thereby contributing to the mitigation of price volatility.

Synergy with the Paks II project and reduction of import dependency

One of the cornerstones of Hungarian energy policy is reducing dependence on electricity imports. Hungary is currently a structural importer, with 20-25% of its annual electricity demand being supplied from abroad, including from the Czech Republic, Slovakia, Austria, Poland and other countries. This entails significant security-of-supply risks, particularly in light of geopolitical tensions, such as the infrastructure-related impacts of the war in Ukraine.

In the current geopolitical, energy-policy and climate-policy context, it is essential to recognise that the existing Paks units will not become redundant once the Paks II NPP is constructed. The figures in the 2024 NECP and system-level modelling, such as calculations by the Institute of Nuclear Techniques of the Budapest University of Technology and Economics (BME NTI), show that due to the upward trend in electricity consumption, the units of the Paks NPP (2,000 MW) and the Paks II NPP (2,400 MW) must operate in parallel in order to keep the share of electricity imports permanently below 20% and to ensure a decarbonised electricity supply.

Together, the six units of the Paks NPP and the Paks II NPP will provide approximately 4,400 MW of clean baseload generation capacity, which will offer a suitable foundation for the system integration of renewable-energy-based power plants, even under future system load conditions.

Conclusions

The SSLE of the existing four units of the Paks NPP until the end of the 2050s is not merely an option, but a strategic interest of Hungary. The measure is fully justified by the following considerations:

- Maintaining physical reality and grid stability alongside the integration of weather-dependent renewables, primarily solar power in the case of Hungary.
- Achieving climate-neutrality objectives by 2050 through the preservation of carbon-free baseload electricity generation.
- Securely meeting growing industrial and residential electricity demand while reducing import dependency.
- Ensuring outstanding economic returns and low consumer electricity prices.

In the SSLE project of the four VVER-440/V213 units of the Paks NPP, the application of modern Hungarian requirements based on international regulatory practice, together with accumulated technical experience, ensures that, through the necessary targeted refurbishments and investments, the units can continue to serve as a solid foundation for the security of Hungary's energy supply, its energy and climate protection strategy, and the development of the economy until the end of the 2050s.

By mid-2022, the assessment of the possibility of a SSLE of the Paks NPP had become timely for both economic and political reasons. In response to the situation that had emerged, the Government of Hungary adopted its decision to commence preparations for the SSLE of the NPP. This amended the previous decision according to which, following the shutdown of the Paks NPP after 50 years of operation, domestic nuclear electricity generation would be limited exclusively to the generation capacity of the two new units of the Paks II NPP.

The activities underpinning the SSLE project also include the present assessment of the environmental impacts associated with the continued operation of the Paks NPP. The purpose of this assessment is to provide a detailed evaluation of the environmental feasibility of the SSLE project and to support the application for the required environmental license.

1.4. Presentation of the applicant and its identification data

The applicant for the environmental license regarding the subsequent extension of the service life of the Paks NPP is the MVM Paksi Atomerőmű Zrt., its identification details and contact information are as follows:

Name:
Abbreviated name: MVM Paksi Atomerőmű Zrt.
Full name: MVM Paksi Atomerőmű Zártkörűen Működő Részvénytársaság (MVM Paks Nuclear Power Plant Private Company Limited by Shares)
Registered site: 7030 Paks, Lot Number: 8803/17.
Surface mail address: 7031 Paks, P.O. Box 71.
Email address: atomeromu@npp.hu
Website: atomeromu.mvm.hu
Switchboard: +36 (75) 505-000
Information and Visitor Center: +36 (75) 507-432, uzemlatogatas@npp.hu

The MVM Paksi Atomerőmű Zrt. operates an environment-centered management system compliant with the MSZ EN ISO 14001:2015 standard to minimize the environmental impact of its operations to the lowest reasonably achievable level and to ensure compliance with regulations,

certified on a regular basis. In accordance with the integrated management policy formulated by the company, it is committed to the environmentally friendly production of electricity, protecting the environment, considering climate change as a key factor, preventing environmental pollution, improving environmental performance and reducing operational risks.

The MVM Paks Atomerőmű Zrt. has reported on its environmental protection activities, as well as on its environmental goals it has set and their implementation in annual environmental protection reports¹ since 2001, since 1995, it has been operating an Information and Visitor Center² and also offers opportunities for organized group visits.

1.5. International practice regarding the extension of NPP service life

The energy supply crises of recent years, geopolitical tensions, increasingly stringent decarbonisation targets, and the ongoing transformation of energy supply technologies resulting in continuously growing electricity consumption have brought about a fundamental shift in global energy policy. It has become evident that scenarios based exclusively on weather-dependent renewable energy sources entail significant grid stability and security-of-supply risks, while consumers and the economies of developed countries require a continuous and reliable electricity supply. Consequently, alongside the construction of new NPPs, the long-term operation (LTO) of existing nuclear generating capacity has become the primary and most cost-effective instrument worldwide for achieving energy independence and climate protection objectives.

International regulatory trends for NPPs are now clearly moving towards total operating lifetimes of 60, 70, or even 80 years, particularly in the case of robust pressurised water reactor technologies (Western PWRs³ and VVERs⁴). A review of the activities of several leading countries demonstrates a clear and consistent trend.

The United States Nuclear Regulatory Commission (US NRC) has established one of the world's most stringent yet predictable regulatory frameworks through the Subsequent License Renewal (SLR) program. While the original operating licences of NPPs were issued for 40 years, the first 20-year licence renewal programs extended operation to 60 years. The SLR program specifically targets the safe operation of NPPs between 60 and 80 years of service life and can essentially be regarded as the U.S. equivalent of the SSLE project discussed in this documentation for the Paks units. Under the SLR program, particular attention is paid to the ageing mechanisms affecting non-replaceable components (such as the reactor pressure vessel), concrete structures, and underground cable systems, while also addressing the necessary equipment replacements and refurbishment activities. The regulatory objective is clearly to enable operating licences to be renewed successively, potentially multiple times, for as long as safe operation can be demonstrated. The licensing framework allows operation up to 80 years and potentially beyond.

In Switzerland, the Beznau, Gösgen and Leibstadt NPPs provide approximately one-third of the country's electricity generation. An official report commissioned by the Swiss Federal Government and published in May 2026 concluded that operation of the Gösgen and Leibstadt units for 80 years is both technically feasible and economically viable under market conditions. Achieving this objective would require modernisation investments of approximately CHF 0.7-1.2 billion per unit. Lifetime extension is considered critical for avoiding winter electricity shortages and excessive dependence on imports.

In Sweden, a major shift in energy policy is reflected in the strategic decision of Vattenfall. The utility company and its partners have adopted a principal decision to extend the operating lifetimes of the Forsmark and Ringhals NPPs (a total of five units) from 60 to 80 years. This decision is expected to provide Swedish consumers and industrial electrification efforts with approximately 800 TWh of clean electricity through the 2060s. The required investments are estimated at

¹ <https://atomeromu.mvm.hu/Rolunk/Kozerdeku/Jelentesek>

² <https://atomeromu.mvm.hu/hu-HU/Latogatoknak/TajekoztatoEsLatogatokozpont>

³ Pressurized water reactor.

⁴ Water-cooled, water-moderated energetic reactor.

SEK 40-50 billion (EUR 3.7-4.6 billion) and are planned for implementation during the 2030s through the replacement of turbines, condensers, and instrumentation and control systems.

France, the European Union Member State with the largest nuclear generating capacity, is also making significant efforts to extend the operating lifetimes of its NPPs. The French licensing process follows a unique two-stage approach. The French Nuclear Safety and Radiation Protection Authority (ASNR) first grants a fleet-wide generic approval for reactors of the same type, followed by individual ten-year periodic safety reviews and licensing procedures for each unit. Regarding fleet-level generic approvals, lifetime extension from the original 40 years to 50 years has currently been approved for a total of 52 units in France, including all 32 units of the 900 MW fleet and 20 units of the 1,300 MW fleet. Following the generic approval, the finalisation of individual unit licences proceeds continuously according to schedule. In France, all NPP units are required to undergo a comprehensive periodic safety review every ten years. Successful completion of this review is a prerequisite for the actual extension of the operating lifetime of a given unit. (It is worth noting that France also operates four 1,450 MW N4-type units and one 1,600 MW European Pressurised Reactor (EPR) unit, which are currently too young for lifetime extension beyond 40 years to be relevant.)

In Belgium, the plans for a complete nuclear phase-out were abandoned in response to the war in Ukraine and the subsequent energy crisis. The Belgian Government initially decided to extend the operating lifetimes of the two newest units, Doel 4 and Tihange 3, by ten years. The European Commission approved the Belgian state support package, which is based on a Contract-for-Difference (CfD) pricing mechanism designed to ensure long-term investment returns, as well as on the establishment of BE-NUC, a 50-50% public-private joint venture between the Belgian State and Engie/Electrabel. In the spring of 2026, the Belgian Government suspended the dismantling of previously shut-down reactors, thereby preserving the possibility of their future restart in response to increasing geopolitical risks.

The Dutch Government has placed nuclear energy at the centre of its climate and energy policy. Recently, amendments to the Nuclear Energy Act were submitted to enable the operating lifetime of the country's sole NPP, Borssele, to be extended from the currently established closure date of 2033 to 2054. In parallel, the state-owned company NEO NL was established to develop and operate two new large-capacity nuclear power units.

In Finland, the VVER-440 units of the Loviisa NPP, operated by Fortum, have received a licence from the Finnish Government licensing operation until 2050, corresponding to a total operating lifetime of 70 years. To maintain safety and reliability, a EUR 1 billion modernisation program consisting of ten major elements is being implemented.

In the Czech Republic, the energy company ČEZ has announced that preparations have commenced for achieving an 80-year total operating lifetime for the four VVER-440/V213 units of the Dukovany NPP. These units are essentially identical to Units 1-4 of the Paks NPP and were originally rated at 440 MW, with output subsequently uprated to approximately 500 MW. The Czech Ministry of Industry and Trade has emphasised that an 80-year operating lifetime is not intended to replace new nuclear construction projects, but rather to complement them logically as part of the national energy strategy.

The international overview presented above clearly demonstrates that the SSLE of the Paks units is fully consistent with international trends. From both strategic energy policy and technical perspectives, Hungary is preparing to take steps similar to those adopted by many other countries regarding the lifetime extension of existing NPPs. Such projects are not only technically feasible and safe but also represent the financially optimal solution for maintaining carbon-neutral baseload electricity generation.

The plans of several countries further demonstrate that newly constructed units – such as Paks II NPP, the planned new Czech nuclear units, and the Swedish and Dutch projects – are not intended to replace, but rather to complement, the extended-lifetime light-water-cooled and light-water-moderated NPPs built during the 1970s and 1980s. Only through this combined approach can future growth in electricity demand be reliably supplied with continuously available, carbon-neutral electricity.

1.6. Licensing procedures required for the SSLE

In addition to the environmental licensing procedure, the nuclear safety licensing procedure under the jurisdiction of the HAEA must also be conducted to extend the service life of the NPP, a separate application must also be submitted to the Hungarian Energy and Public Utility Regulatory Authority to extend the validity period of the NPP's electricity generation operating license. Figure 1.6-1. provides an overview of the entire licensing process and its legal framework.

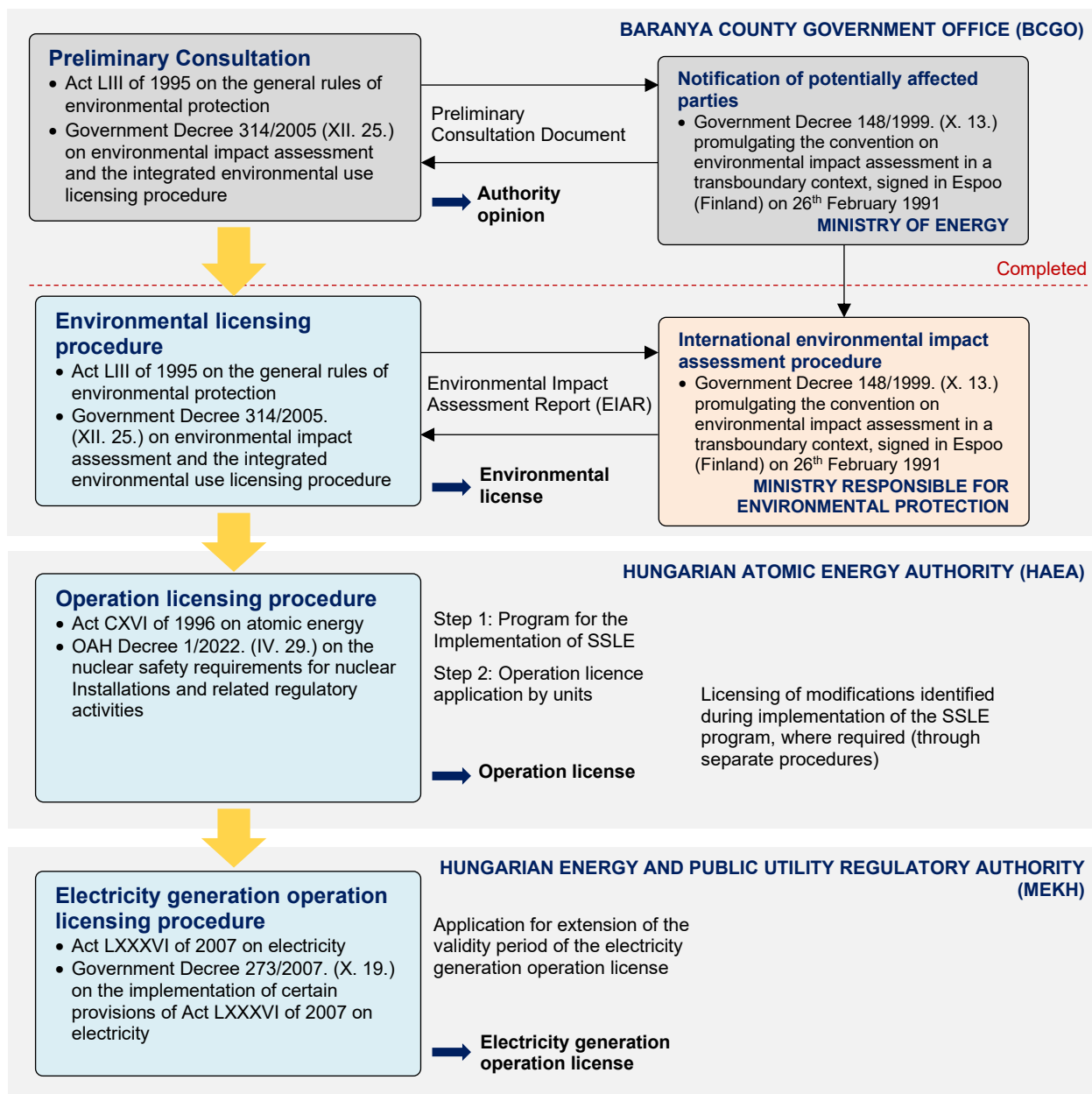


Figure 1.6-1. Licensing process for the NPP SSLE

Environmental licensing procedure

Pursuant to Act LIII of 1995 on the general rules of environmental protection, an environmental impact assessment must be conducted, and an environmental license must be obtained from the competent environmental authority prior to the commencement of activities that have a significant or expectedly significant impact on the environment. The scope of these activities, as well as the method and phases of the environmental licensing procedure and the content requirements for documents to be submitted to the environmental authority, are set forth in Government Decree 314/2005. (XII. 25.).

The preliminary consultation, which may be requested for activities subject to an environmental impact assessment, was conducted in September-October 2024 at the BCGO, as the competent environmental authority. The environmental protection authority issued its opinion concluding the preliminary consultation, taking into account the comments of the administrative and other bodies involved in the consultation. The authority's opinion includes additional tasks and considerations – in addition to the general requirements set forth in the relevant legislation – related to the preparation of the environmental impact assessment, which were taken into account in the preparation of the environmental impact assessment report.

The operation of NPPs is an activity, subject to the Convention on the Assessment of Transboundary Environmental Impacts, signed in Espoo, Finland, on February 26, 1991 and promulgated by Government Decree 148/1999. (X. 13.), which has a potential to result in significant transboundary environmental impacts. In connection with the preliminary consultation, the Ministry of Energy sent a notification to interested foreign parties regarding the planned activity as well as the ongoing procedure.

Taking into consideration that – as described in *Chapter 1.1.* – several countries have indicated their intention to participate in the impact assessment procedure, the procedure must be continued in accordance with the provisions of the Espoo Convention (international environmental impact assessment procedure). In the course of this, the environmental impact assessment and related documents will be sent to the foreign interested parties, and a consultation will be conducted to ensure that the interested foreign parties are informed and their opinions are obtained. The environmental protection authority takes into account the opinions and comments received from foreign interested parties during the international procedure when developing its decision regarding the environmental license.

Operating license procedure

As set forth in Act CXVI of 1996 on nuclear energy, the nuclear regulatory authority, namely the HAEA, is responsible for issuing the nuclear safety licenses required for the continued operation of the nuclear facility beyond its design service life. Pursuant to OAH Decree 1/2022 (IV. 29.) on the nuclear safety requirements for nuclear facilities and related regulatory activities, an operating license issued by the HAEA, the nuclear safety authority, is required for the subsequent extension of the NPP's service life. Obtaining an environmental license is a prerequisite for the issue of a nuclear safety (operating) license for the SSLE.

The nuclear safety licensing procedure is a two-step process. As the first step of the procedure, four years prior to the expiration of the operating license for Unit 1, the implementation program for the SSLE of Units 1-4 of the Paks NPP is submitted to the HAEA, concurrently with the official notification of the intention to pursue a SSLE. The implementation program shall specify all actions necessary to ensure that the safety of the NPP can be established and continuously maintained in a verifiable manner and that the licensing requirements set forth can be met. The HAEA approves the implementation program – provided that it meets the requirements set forth in the HAEA regulation – and monitors its implementation. Permits required to carry out modifications arising during the implementation of the SSLE program must be obtained separately within the validity term of the current operating license, in accordance with the rules that apply to the licensing of the relevant activity.

In the second stage of the procedure, one year prior to the expiration of the operating license for the given unit, applications for an operating license covering the period of the SSLE are submitted to the HAEA, separately for each unit. The documentation supporting the license includes a review of the units' design basis; a review and development of aging management programs for the power plant as a whole and for its specific system components; an assessment of the power plant's technical condition; the verification of its suitability for continued operation; as well as the necessary measures based on the results of the analyses.

The reviews and analyses to be conducted are carried out partly in parallel with the environmental licensing process and continuously during the preparation period for the SSLE. The HAEA licenses the planned SSLE in a new operating license issued at the licensee's request.

The HAEA renews the operating license based on its safety assessment, therefore, the procedure covers all systems classified under nuclear safety categories that must perform their intended safety functions throughout the entire service life. System components without safety functions must also be included in the scope of the assessment if their failure could hinder, affect or endanger systems or system components with safety functions in the performance of their tasks.

To justify the SSLE, it must be demonstrated that the condition of the system components allows for continued operation. Inspections of the condition of the NPP's systems and structural components have been ongoing since commissioning. Beyond the routine condition-monitoring inspections and those conducted in accordance with NPP practices, special inspections will also be carried out in line with the scope and methodology agreed upon with the regulatory authority, to assess the condition of all critical system components and structural elements. Based on these inspections to be performed, it must be demonstrated that the NPP's building structures and equipment are in a condition suitable for continued operation, are free of defects and that the material property values exceed the required values.

The Paks NPP has implemented aging management programs, that detect the aging processes of buildings, building structures and system components in a timely manner, in order to effectively prevent the effects of aging, capable of reducing, or repairing any deficiencies that may occur. During preparations for the SSLE, these programs will be reviewed and new programs will be developed as necessary. Verification of the suitability of these programs constitutes an important section of the licensing documentation required for the SSLE. Verification of the suitability of the aging management programs also involves a comprehensive review of previous aging management practices, with necessary modifications to existing programs and, in some cases, the development of new ones.

The service life of the Paks NPP is determined by those structures and system components (e.g., reactor pressure vessel, steam generators) that cannot be replaced or refurbished (long-life components), or where the associated costs and downtime are so enormous that replacement is not reasonable from technical-economical perspectives. One of the most important issues regarding the SSLE is whether the expected service life of the non-replaceable major technological equipment is sufficient to support an additional 20 years of operation.

Based on the currently available results of material testing, analyses and maintenance, none of the equipment critical to nuclear safety is expected to become inoperable or incur excessive costs during the extended service life of 50+20 years. All available technical information indicates that the NPP's operability for 70 years is most likely to be demonstrated.

The most important condition for the SSLE is that the systems, structure, components and buildings and structures remain in a technical condition (availability) that meets the requirements during the extended operating period. To this end, taking into account the extension of the service life to 50+20 years, the NPP's experts have developed a reconstruction program based on the current and projected condition data of the mechanical, electrical, instrumentation and control systems, system components, buildings and structures. The reconstruction program will be implemented primarily during scheduled major overhauls and the in-service maintenance of safety systems.

Producer's operating license procedure

Pursuant to Act LXXXVI of 2007 on electric energy, electricity generation at the NPP may be carried out only with an electricity producer's operating license issued by the Hungarian Energy and Public Utility Regulatory Authority. In the case of a NPP, the validity term of the producer's operating license may be extended no earlier than five years prior to the expiration of the license. An application for the extension of the term of the producer's operating license must be submitted no later than 180 days prior to the expiration of the license. The detailed rules for licensing are set forth in Government Decree 273/2007. (X. 19.) on the implementation of certain provisions of Act LXXXVI of 2007 on electric energy.

2. The site of the NPP and the technology of nuclear power generation

2.1. The site and the surroundings of the NPP

The Paks NPP site is located in the South-Transdanubian region of Hungary, on the eastern border of Tolna County, 1 km west of the River Danube, at river kilometer 1527 and 1.5 km east of Main Road No. 6 (*Figure 2.1-1.*). The site is located 118 km south of Budapest and 5 km south of the center of Paks. The nearest section of the national border is to the south, 63 km away in a straight line and 94 km downstream along the Danube; the border runs at river kilometer 1433.

The Paks site is located within the administrative territory of the town of Paks, in the urban area; the site is divided into the following three main sections:

- The operational area of Units 1-4 of the Paks NPP:
Units 1-4, operated by MVM Paks Atomerőmű Zrt., along with the connecting turbine hall, water intake plant, auxiliary equipment and systems necessary for their operation, the cold and warm-water channels, as well as offices, maintenance and storage facilities are located in this section of the site.
- The area of Units 5-6 of the Paks II NPP:
The area located north of the existing Units 1-4 of the NPP, which has been designated for the construction of the new Paks II NPP (Units 5-6) being built by Paks II. Atomerőmű Zrt. Construction work on Units 5-6 is currently underway in the project area.
- The operational area of the Spent Fuel Interim Storage Facility for (SFISF):
Located southwest of the operational area of Units 1-4, this site houses the SFISF, maintained by the Public Limited Company for Radioactive Waste Management (PURAM) as the licensee of the nuclear facility, along with other related buildings and structures.

Figure 2.1-2. shows a satellite image of the power plant site and its immediate surroundings, indicating the construction area of the Paks II NPP and the SFISF site. The figure also shows the installation area for the structures and equipment of the alternative warm-water channel section and the peak cooling system planned to be constructed as part of the preparations for the SSLE of the Paks NPP. The construction of the latter will be necessary for the period of concurrent operation of the Paks NPP and Paks II to ensure cooling – before the release of warmed cooling water taken from the Danube back to the river – to reduce the thermal load on the Danube (A technical description of the planned modification is provided in *Chapter 2.4.*)

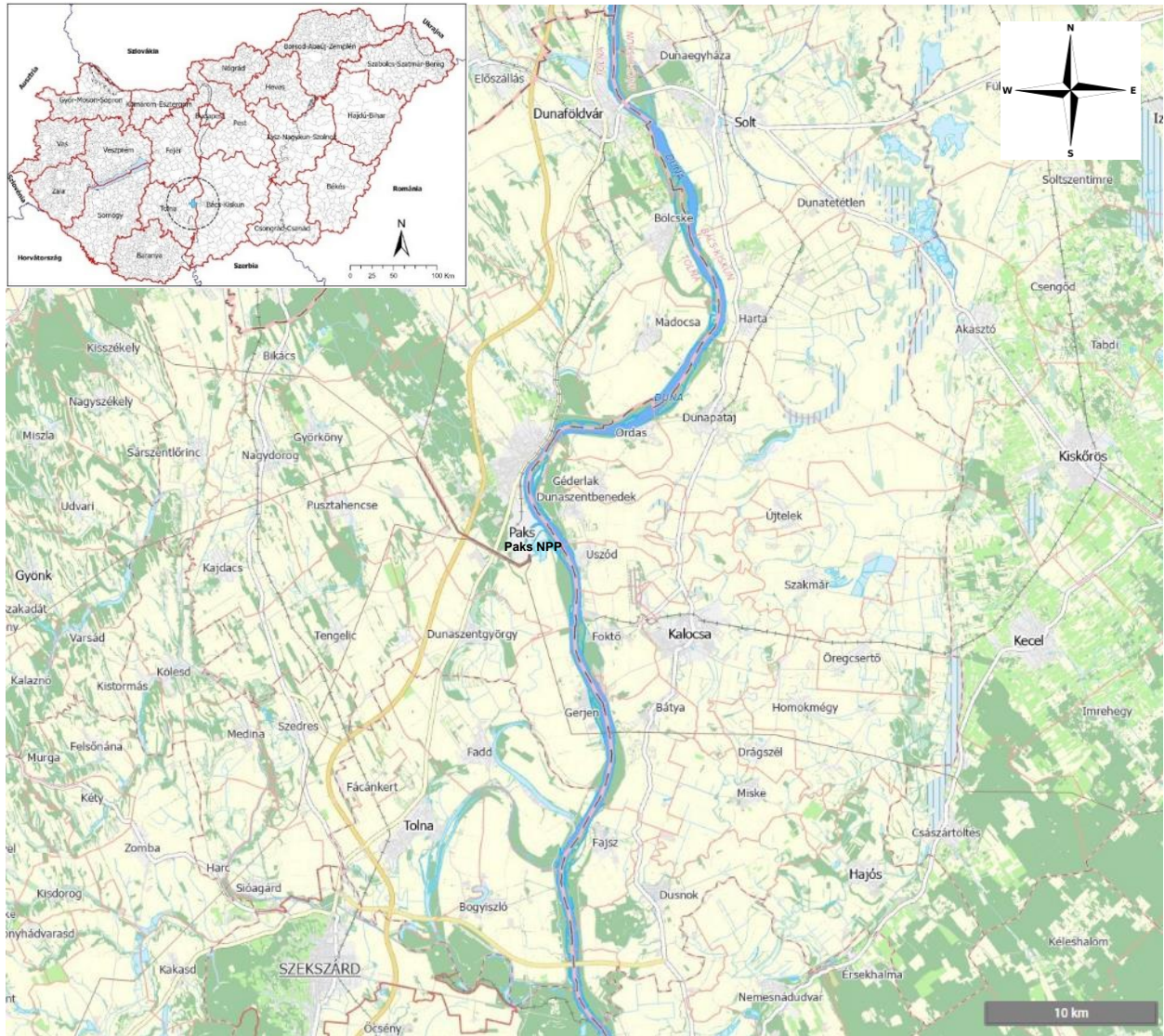


Figure 2.1-1. The site and the surroundings of the Paks NPP

The operational areas of Units 1-4 of the Paks NPP are owned by MVM Paksi Atomerőmű Zrt., while the Paks II NPP site is owned by Paks II. Atomerőmű Zrt. Beyond the actual operational areas, the reserve operational area, fish ponds, access routes and forests are considered as off-site areas.

The Paks NPP site is surrounded by a safety zone, designated by the HAEA in a decision pursuant to Government Decree 246/2011. (XI. 24.) on the safety zones of the nuclear facility and the radioactive waste repository.

The surface distance of the safety zone is 500 m, measured from the plane of the NPP's outermost wall representing its technological protection. A similar 500-meter safety zone has been designated also around the SFISF and Paks II NPP sites adjacent to the Paks NPP site. The restrictions set forth in the government decree apply within the safety zones.

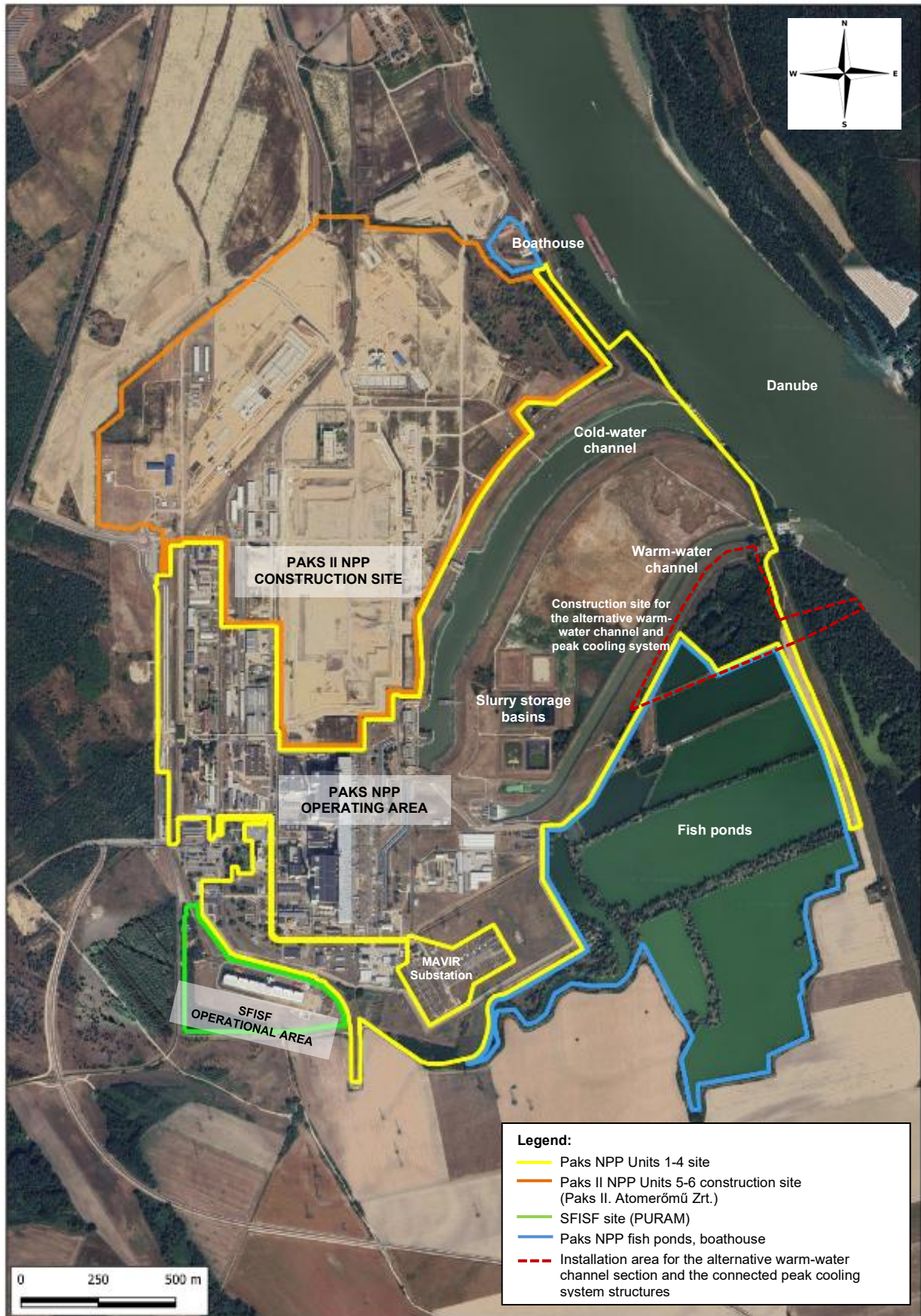


Figure 2.1-2. Satellite image of the Paks NPP site and its surroundings, showing the Paks II NPP construction area and the SFISF site

2.2. Other existing and planned nuclear facilities at the Paks site

The SFISF, operated by PURAM is located in the area immediately adjacent to the Paks NPP's operational site. In the north, the area directly adjacent to the lot of Units 1-4 of the Paks NPP, is the site designated for Units 5-6 of the Paks II NPP, which is being built as part of the Paks II. Atomerőmű Zrt. investment project.

The current strategy for managing spent fuel from the Paks NPP involves placing the spent fuel assemblies in interim storage for an extended period until a decision is made regarding its reprocessing or final disposal. After the spent fuel is removed from the reactors of the NPP, it is placed in a water-filled "spent fuel pool" in the plant for a period of 3-5 years. Once the required cooling period has elapsed, the fuel assemblies are transported from the NPP to the SFISF (Figure 2.2-1.). For transport, the spent fuel assemblies – up to 30 at a time – are loaded into a water-filled transport container cask in the NPP. The container is then transported by rail on a freight wagon equipped with a specially designed support structure to the interim storage facility neighbouring the NPP.



Figure 2.2-1. The SFISF and the main buildings of the Paks NPP

The SFISF is a modular, vault-type, passively cooled interim storage facility that provides dry storage for spent fuel assemblies. The receiving area of the storage facility and the first – three-vault – storage module was commissioned in 1997. In accordance with the facility's modular design, the newer four- and five-vault modules are being expanded in line with the rate of generation of spent fuel assemblies in the Paks reactors. By the end of 2025, a total of 28 storage vaults have been commissioned. According to current plans, interim storage will last for at least 50 years.

Based on data from the end of 2025, 11,317 spent fuel assemblies are stored at the facility. The planned and licensed storage capacity of the facility was determined by taking into account the number of spent fuel assemblies being generated during the first 20-year service time extension of the Paks NPP. Accordingly, with the construction of a total of 33 storage vaults, the facility's storage capacity will be 17,743 fuel assemblies.

PURAM plans to carry out the interim storage of the nearly 6,200 spent fuel assemblies to be generated during the subsequent 20-year service life extension at the current SFISF site. Preparations for this – including environmental licensing – began already in 2025.

Pursuant to the agreement between the Government of Hungary and the Government of the Russian Federation on cooperation in the peaceful use of nuclear energy, two new VVER-1200, V-527-type reactor units with a nominal thermal output of $3200 \pm 128 \text{ MW}_{th}$ capable of supplying district heating (Units 5 and 6 of the Paks II NPP) will be designed, constructed and commissioned at a site adjacent to the Paks NPP.

For the two units of the Paks II NPP – similar to the system used for Units 1-4 of the Paks NPP – freshwater cooling taken from the Danube is planned to be used for cooling the condensers. The required volume of cooling water is going to be pumped from the cooling water intake channel

shared with the Paks NPP by pumps at the Paks II NPP's own water intake facilities. The warmed cooling water is returned to the river via the Paks II NPP's own warm-water channel.

The possibility of cooling the warmed cooling water prior to its return to the Danube is ensured by a so-called peak cooling system consisting of rows of cooling cells. The conceptual design of the Paks II NPP, showing the buildings of the Paks NPP, is shown below in *Figure 2.2-2*.



Figure 2.2-2. Visual design of the Paks II NPP

2.3. The technology of electricity generation and the related facilities

The operation of the Paks NPP during the extended service life period is planned using the power plant technology, generation capacity and material usage characteristics that are currently in use, with the continued operation of the existing electricity generation equipment and infrastructure. However, as a result of technical analyses and feasibility studies related to the preparation for the SSLE, MVM Paks Atomerőmű Zrt. has planned several technical and technological modifications as well, whose environmental impacts arising from their implementation and the operation of the modified systems, had to be analysed and evaluated in the environmental impact assessment. These planned technical modifications are described in detail in *Chapter 2.4*.

The main technological facilities of the Paks NPP – relevant from the perspective of expected environmental impacts – and their functions will not fundamentally change due to the SSLE. However, the duration of their life in operation will extend. The technical conditions for the continued operability of the existing equipment are ensured by the maintenance and reconstruction activities currently being carried out on an ongoing basis.

2.3.1. Technology and main technical characteristics of the Paks NPP

The Paks NPP operates four VVER-440/213 reactors in a twin-unit configuration. The name VVER is an abbreviation for “water-water energetic reactor”. The number “440” refers to the nuclear power unit’s original nominal electrical output of 440 MW (the plant’s design total electrical output thus amounted to 1,760 MW), while the number “213” is the reactor model number. Since the commissioning of the first unit, the electrical output of Units 1-4 has increased, as a result of modernization efforts carried out at the plant, to 470 MW per unit in the first phase and

subsequently, through further power uprates to 508.6; 506.0; 506.0; and 506.0 MW per unit, respectively. The total rated electrical capacity of the Paks NPP has thus risen to 2,026.6 MW.

The reactor units are a combination of pressurized-water cooled thermal reactors, light-water-moderated – decelerating fast neutrons to maintain the chain reaction that generates power – reactors that operate with a saturated steam cycle. Each unit comes with a two-island design, consisting of the radioactive primary circuit and the non-radioactive secondary circuit. Schematic diagram of the main equipment of the NPP units and the theoretical operation of the power plant cycle can be seen in *Figure 2.3.1-1*.

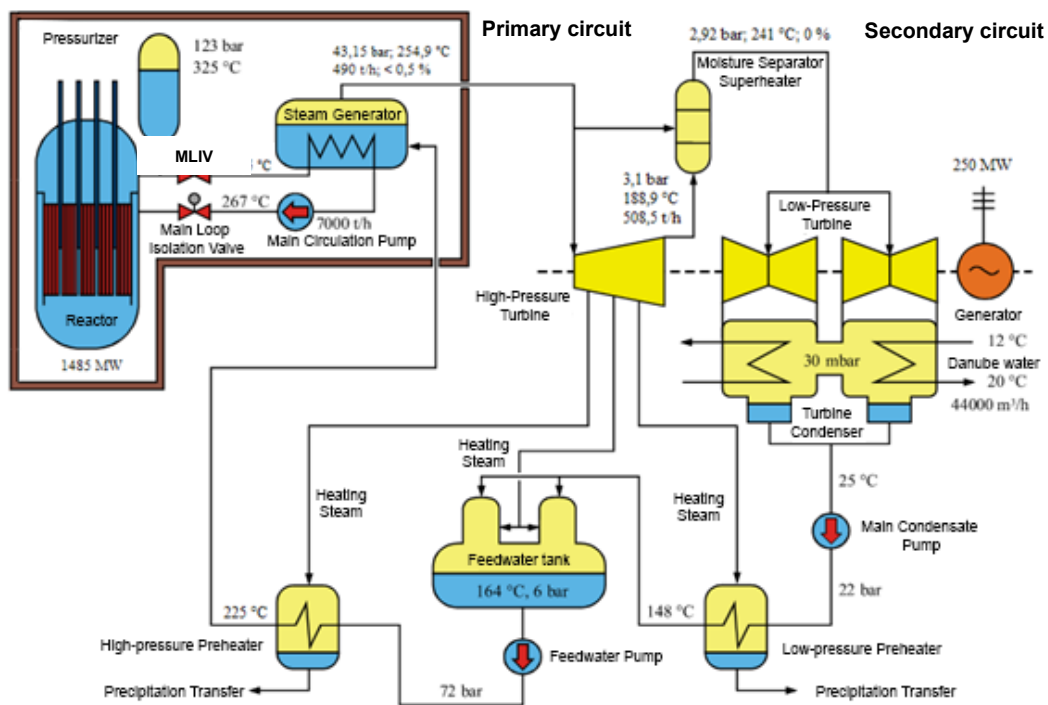


Figure 2.3.1-1. Schematic diagram of the main equipment involved in nuclear power generation

The energy generated by the fission of ^{235}U isotopes in the uranium dioxide fuel of the fuel elements located in the reactor core of the NPP unit, induced by thermal neutrons, is absorbed by the coolant of the primary circuit (high-pressure, high-temperature water). The water in the primary coolant line is kept under high pressure, which prevents it from boiling even at high operating temperatures. The heated primary circuit water is conveyed into the steam generator, where it transfers its heat to the water in the secondary circuit through small-diameter tubes. The pressure of the water in the secondary circuit is much lower than that in the primary circuit, so the heated water starts to boil in the steam generator. From there (after moisture separation), the steam is directed to the high-pressure and then the low-pressure turbines. The saturated steam drives the turbines. The generators driven by the turbines produce electric energy. The steam exiting the turbine condenses in the condenser, from where, after preheating, it returns to the steam generator. The primary and secondary circuit water does not mix: Radioactive materials that have entered the coolant remain in the primary circuit and do not get released into the turbine or the condenser. The vapor-phase coolant in the secondary circuit cools down as heat is converted into mechanical energy and the residual heat is released by heating up the water on the flow side of the condensers, which is cooled by water from the Danube. The warmed cooling water is returned to the Danube.

The NPP operates as a base-load plant with a relatively steady load. The generated electricity is connected to the national power grid at voltage levels of 400 and 120 kV.

In pressurized water reactors (PWRs), the cooling water circulates in a closed primary circuit that also contains the reactor with no direct connection to the outside world. The primary circuit consists of a vessel-type reactor, six parallel loops and a pressurizer connected to one of the

loops. Each loop is equipped with a main circulation pump, a steam generator and two main loop isolation valves, as well as stainless steel piping connecting the equipment. The function of the reactor vessel is the safe generation, and transfer of thermal energy produced by the controlled, self-sustaining nuclear chain reaction occurring in the core in the primary circuit. The reactor vessel is a vertically positioned, cylindrical vessel with an elliptical head and bottom.

The core is the part of the reactor where a large amount of thermal energy is released through the controlled nuclear chain reaction. The core consists of a total of 349 hexagonal prism-shaped fuel assemblies, comprising 312 fixed fuel assemblies and 37 movable control and safety rods. The core has a diameter of 2.66 m and a height of 2.5 m. The fuel element bundles are secured at the bottom by the basket and by the lower plate of the guiding-tube unit from atop, ensuring vibration-free grip.

The Paks NPP uses low-enriched ceramic uranium dioxide fuel. Fuel assemblies are the basic units of the nuclear fuel in NPPs operating with VVER-440/213 reactors and their primary function is to generate thermal energy through the fission of fissile material. The Paks NPP currently operates on a 15-month fuel cycle, with fuel assemblies spending multiple cycles in the reactor.

Since the commissioning of the four units – for NPPs built according to Russian designs – the Russian supplier TVEL has supplied and continues to supply the fuel required for the operation of the Paks NPP. The NPP – in accordance with its development strategy on nuclear fuel consumption, while also taking supply security considerations into account – will begin to expand its fuel procurement sources by involving two additional manufacturers (the French-Russian joint venture Framatome-TVEL and the American company Westinghouse) yet before the start of the SSLE. Regarding the two additional suppliers, the Framatome-TVEL joint venture will not modify the parameters of the supplied assemblies. In the case of these fuel assemblies, the procurement involves fuel assemblies that are partially sourced from a different supplier (the joint venture) but have parameters fully identical to the currently licensed fuel assembly types. From the perspective of environmental licensing, this change affects only the name of the supplier. In the case of Westinghouse manufactured fuel assemblies, the technical parameters – which were jointly determined by the manufacturer and experts from the Paks NPP – will change to a lesser extent. Compared to the TVEL fuel assemblies currently in use – despite the minor differences in parameters – the Westinghouse fuel does not result in any significant change in the environmental impacts of the NPP's operation or the interim storage provided by PURAM.

The function of the main loop (main circulation pipeline and main loop isolation valve) is to convey the primary coolant, heated by the thermal energy generated in the reactor core, from the reactor's outlet nozzle to the steam generator, from where the cooled medium is returned to the main circulation pump and then to the reactor inlet nozzle. The main loop isolation valves located in the cold and warm legs of the loops are designed to isolate the section of the loop containing the steam generator and the main circulation pump from the reactor when necessary. The function of the main circulation pump is to circulate the primary coolant through the reactor, the primary loops and the steam generators, thereby ensuring the transfer of thermal energy generated in the reactor to the steam generator, as well as the cooling of the fuel assemblies.

The function of the steam generator is to transfer the thermal energy generated in the reactor to the secondary coolant, thereby producing the dry saturated steam required to drive the turbines. The steam generator is a horizontally arranged, suspended, cylindrical heat exchanger with heat transfer tube bundles and elliptical covers at both ends. The primary circuit coolant flows through the tube bundles, which ensures the production of dry saturated steam on the secondary side by transferring heat from the primary circuit coolant to the secondary circuit coolant and hermetically separates the radioactive, closed primary circuit from the also closed secondary circuit.

The function of the volume-compensating and pressure-maintaining system is to build up pressure during unit startup and maintain the circuit at a constant pressure in so-called steady-state (steady) mode, as well as to limit pressure fluctuations during transient modes of operation. In addition to maintaining pressure, an important function of the pressurizer is to regulate the water volume in the primary circuit.

The function of the secondary circuit is to ensure heat removal from the primary circuit via the steam generators, to deliver the dry saturated steam produced in the steam generators to the two

so-called turbine sets (interconnected steam turbine and generator) and to return the resulting condensate to the steam generators.

The thermal and kinetic energy of the steam produced in the steam generators must be converted into mechanical rotational motion to drive the generator and thereby generate electricity. In this energy conversion process, the steam turbine's role is to convert the thermal energy of the saturated steam produced in the steam generators into mechanical energy (rotational motion), thereby contributing to the process of secondary circuit heat sink. Each power plant unit is equipped with two turbine groups.

The operation of numerous systems and equipment in the NPP requires an adequate supply of cooling water. The NPP's cooling water system consists of the essential cooling water system, the component cooling water system and the condenser cooling water system. The cooling water requirements of all three subsystems, though according to different technological requirements, are supplied from the Danube. The necessary water volumes are supplied by the water intake facilities associated with Units 1-2 and Units 3-4, respectively, via the NPP's cold-water channel.

The four units of the Paks NPP generate electricity for the National Electric Power System as a base-load power plant, which is fed into the national grid via 400 kV and 120 kV substations. The two main transformers associated with each reactor unit are connected via a common 400 kV feeder to the 400 kV substation, which is part of the national base grid. The 400 kV system supplies the 120 kV substation via two transformers, which transmits the generated energy to the national main distribution network. The Paks substations are connected to the 400 kV national backbone grid via five transmission lines running in different directions, while they are connected to the 120 kV national main distribution grid via transformers and seven transmission lines.

In the event of an unexpected failure or loss of power on the NPP's internal power grid, the diesel generator sets, that belong to the given unit, startup automatically and, by connecting to the emergency power supply network, ensure the power supply to the affected technological systems as an independent power source. There are 3 diesel generators installed per unit (12 in total at the power plant). The diesel generators remain on standby during normal operation of the units. They start only during operating conditions deviating from normal operation, as well as during the periodic functional tests that last a few hours each year.

MVM Paks Atomerőmű Zrt. continuously monitors the condition and reliability of all its safety-critical equipment – including the emergency diesel generators and their associated auxiliary systems – which also encompasses the future availability of spare parts and maintenance support for these equipment. In the case of emergency diesel generators, MVM Paks Atomerőmű Zrt. has decided to install a new diesel generator, the so-called emergency backup diesel generator for Units 1 and 2. The emergency backup diesel generator is a reserve device capable of fully replacing any inoperative emergency diesel generator in the safety systems of Units 1 and 2 in the event of failure (malfunction) or planned inoperability (e.g., diesel engine overhaul or change). The type of the new diesel generator has not yet been determined. It will be selected later through a competitive bidding process.

The emergency backup diesel generator will be essentially in cold standby mode. In case any of the emergency diesel generators gets tripped, it will take its place and enter a ready-to-operate state. Like the other emergency diesel generators, it must undergo regular functional tests. The periodicity of these tests will be determined by the manufacturer's specifications.

In the event of beyond design base accident in the NPP's systems, the electrical power supply for the mechanical, electrical as well as the instrumentation and control systems involved in accident management is provided by one diesel generator unit, each located in the northern and southern accident diesel generator compartments. During normal operation, the accident diesel generators operate only during periodic functional tests lasting a few hours each year.

2.3.2. Related activities and facilities

2.3.2.1. Water supply, waste water treatment

The facility's water usage can be divided into two main categories based on function:

- For cooling purposes, the power plant intakes water from the Danube through an open cold-water channel which, after use is returned to the Danube as the receiver via an open-section warm-water channel.
- The industrial water used to replenish the power plant's technological water losses comes from the Danube water intake. The source of fire water is the riverbank-filtered well field (with a warm-water channel reserve) and the drinking and service water is supplied by the complex field of Csámpa with 9 deep-drilled wells (confined groundwater).

The committed annual water demand is 2.9 billion m³/year from surface water abstraction and 200,000 m³/year from water wells.

A sewage network is in operation in the area of the Paks NPP. The municipal wastewater treatment plant with a capacity of 1,870 m³/day, serves as the receiving and treatment facility for the power plant's municipal wastewater as well as wastewater from the medical and laboratory buildings and, from time to time, excess water. The wastewater treatment plant consists of two process lines, each employing a complete biological treatment system with activated sludge, utilizing mechanical treatment and total oxidation processes. Excess sludge is transferred to sludge drying beds.

The treated wastewater discharged from the municipal wastewater treatment plant is conveyed via a steel pipeline into the warm-water channel directly in front of the energy dissipator structure. Before the discharge point into the channel there is a sampling well, which is the power plant's sampling point V3.

The excess sludge discharged from the secondary clarifier is conveyed to a sludge thickener, where the sludge liquor is separated from the sludge. The thickened sludge is transported through the sludge pipeline to the sludge bed for further drying. After the dried sludge is tested for radioactive concentration, it is disposed of depending on the test results. If it does not need to be treated as radioactive waste, it is classified as hazardous waste and disposed of in accordance with regulations on hazardous waste.

As a receiving basin for wastewater from the backwash of filters installed at the water intake plant, waste removed with water at the rake screens and other wastewater originating from the water intake process, the section of the warm-water channel immediately downstream of the weir serves.

The treatment of wastewater from the water softener plant is part of the power plant's industrial sludge system. Its function is to receive and treat chemical wastewater and discharge the treated water into the receiver. The treatment of wastewater from the water softener is accomplished in two stages. The first stage consists of spontaneous neutralization occurring in the suction well of the pumping station. The second stage is the sludge storage basin, where the phase separation and sedimentation takes place. Two 10,000 m³ sludge storage basins are available for the treatment and sedimentation of wastewater from the water softening plant. From the sludge basin, the treated (purified) water flows by gravity through an overflow into the warm-water channel. Observation wells have been installed in the vicinity of the sludge storage area to monitor seepage and groundwater quality.

Wastewater including oils is treated at its point of origin. At the car wash, the treated wastewater is directed into the power plant's municipal wastewater system while, at other points of origin (fire station car wash, barrel oil storage, truck wash), it is discharged into the power plant's stormwater drainage network after appropriate treatment.

The stormwater drains carry roof runoff from the buildings and stormwater collected from roads and green areas into the ditches running along the outer perimeter of the power plant. There are 5 main stormwater collection drains on the site of the Paks NPP. The on-site stormwater drainage network connects to the perimeter drainage system outside the plant site. The cold-water channel

receives the stormwater carried by the North Perimeter Channel, while the warm-water channel receives the stormwater directed into the South Perimeter Channel.

2.3.2.2. Freight and passenger transport required for operations

The NPP site can be accessed by road from the north and south via Main Road No. 6, from which two separate access roads (north and south access) lead to the NPP. The site can also be accessed from the south via the Paks-Gerjen connecting road, which connects into the NPP's southern access road. The site can be accessed from the M6 highway by exiting at the Paks-South interchange at the 113 km marker, then taking Route 6232 through the Paks area (Kölesd Road – Dankó Pista Street) and finally turning onto the section of Main Road No. 6 south of Paks to approach from the north. The average road traffic associated with the operation of the NPP is 450 heavy-duty vehicles (typically light trucks) per day during the daytime and 40 vehicles at night; for passenger cars, 1,920 vehicles per day during the daytime and 220 vehicles at night and for buses, 316 vehicles during the day and 58 vehicles at night.

Only special-purpose trains may access the power plant site via the industrial rail line from the Paks railway terminal and only for occasional freight transport. There is no passenger train service. Spent fuel assemblies destined for interim storage at the SFISF arrive from the NPP on a railcar pulled by a diesel locomotive to the SFISF site adjacent to the NPP. Fuel shipments from the power plant currently occur 10-12 times a year, with each shipment taking no more than a few hours. Rail transport is considered therefore occasional in nature and the associated environmental impacts are negligible in terms of volume.

The power plant site is also accessible by waterway. The cold-water channel has a heavy cargo mooring facility. This transport is also occasional, used exclusively for cargo transport so its volume is negligible in terms of the resulting environmental impacts.

For the period of the Paks NPP's SSLE – in connection with the plant's operation – no significant changes are expected in the current freight and passenger transport demands. Considering that the delivery of materials, equipment and other goods used at the NPP is expected to continue at the current frequency and volume and that no significant changes are foreseen in terms of the number of operators and maintenance personnel in the future. The scale of freight and passenger transport related to the activity is estimated to remain consistent with current levels for the duration of the extended operating period.

2.3.2.3. Other related activities and technological systems

There are numerous technological systems at the NPP that, based on their safety classification, do not affect nuclear safety or are not directly related to electricity production. These systems are necessary for the general operation of the plant, their functions include, among others, the handling, transport and storage of hazardous materials and conventional hazardous waste.

2.4. Preparations for SSLE, activities and modifications planned for the continued operation

Based on the results of technical analyses and feasibility studies related to the preparation for the SSLE, MVM Paks Atomerőmű Zrt. plans to implement technical and technological modifications, which were analysed and evaluated during the environmental impact assessment in terms of the nature and significance of the expected environmental impacts. The modifications that are significant and therefore require detailed assessment are summarized below.

2.4.1. Implementaton of the alternative warm-water channel and peak cooling system

The final heat removal from the technological systems of the Paks NPP is achieved through cooling by fresh water from the Danube. For the power plant, located on the right bank of the Danube, cooling water is conveyed to the units via a cold-water channel designed for this purpose

and the warmed cooling water is then returned to the Danube via the warm-water channel. According to the limit on thermal load on the Danube – established by law – a maximum temperature of 30°C is permitted across the entire cross-section at a distance of 500 m downstream from the outlet point. Compliance with the prescribed temperature limit during critical periods is currently ensured by reducing the power plant's electrical output to the necessary extent, which does not affect the maintenance of nuclear safety but results in a loss of production in terms of the NPP's electricity generation.

Climate change is expected to increase the frequency of such periods in the future, during which, with the current heat dissipation system, increasingly severe and frequent power reductions would be required to comply with the 30°C limit. In addition, the number and magnitude of the required power reductions will be further increased by the commissioning of the new Paks units (Paks II NPP).

Following the decision to SSLE of the Paks NPP, the above circumstances necessitated an examination of the measures and technical solutions to ensure long-term compliance with the thermal load limit. Based on the results of the analyses concluded, the MVM Paks Atomerőmű Zrt. plans to construct an alternative warm-water channel branching off from the existing warm-water channel and, in connection with this, a so-called peak cooling system consisting of cooling cells. The planned cooling system, utilizing forced-draft cooling cells, will enable the temperature of the Danube water, heated upon use for cooling purposes at the NPP, to be reduced prior to its return to the river.

The route of the planned alternative warm-water channel section, approximately 950 m in length, branches off from the existing warm-water channel on its right bank, in the section following the pumping station on the belt ditch (*Figure 2.4.1-1.*). The route of the new warm-water channel section crosses the Tolnai Danube Natura 2000 site in the floodplain between the flood protection embankment and the Danube. The new channel section also affects the northern areas of the existing fish ponds.

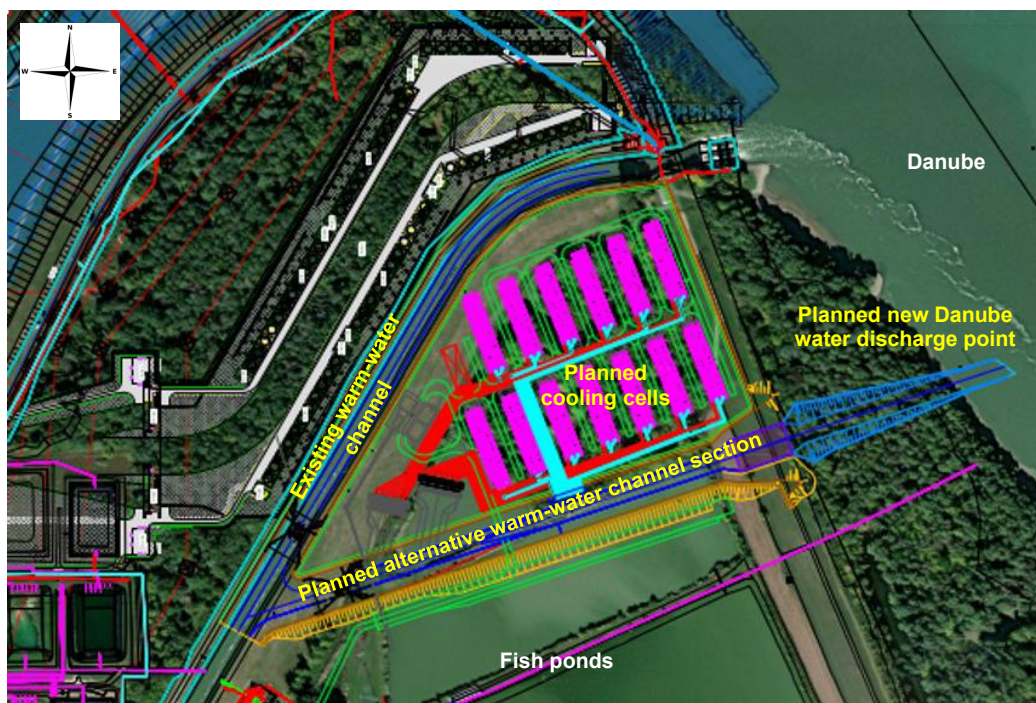


Figure 2.4.1-1. Layout of the alternative warm-water channel section and the connected peak cooling system

The warmed cooling water extracted from the alternative warm-water channel section enters the cooling cells, where it cools as it flows past the cooling inserts and then flows back into the channel by gravity from the basin beneath the cells. The cooling cells contain fan units, which generate the necessary airflow within the cell during heat exchange to ensure the cooling effect. The

cooling cells are operated intermittently, only during specific periods of the year when the high temperature of the Danube water makes it necessary.

2.4.2. Modification of spent fuel storage technology

To ensure the interim storage of spent fuel generated during the NPP SSLE, it will be necessary to expand the capacity of the SFISF, operated by PURAM, the organization responsible for interim storage. The existing SFISF was originally designed with a total of 33 vaults, taking into account the NPP's 30-year design service life. The storage of spent fuel assemblies generated during the first 20-year service life extension period was ensured by expanding the storage facility's capacity and increasing in two stages the number of assemblies that can be stored in a single vault.

Considering that the available spare resources at the SFISF that could be utilized for capacity expansion using the current modular, vault-type dry storage technology has essentially been exhausted, the interim storage of the additional spent fuel assemblies generated during the extended service life is intended to be ensured by applying a new technology within the SFISF's current site. The new technology, developed more than 10 years ago and evidenced by suitable reference facilities, is Holtec International's HI-STORM UMAX system. In this storage technology, the spent fuel assemblies are placed in a thick-walled, welded stainless steel container (Multi-Purpose Canister /MPC/). The term "multi-purpose" refers to the possibility that this packaging unit can be used not only for interim storage but also for the final disposal of spent fuel assemblies. This can be highly advantageous because, in this particular case, no repackaging, or individual handling of the assemblies will be required for final disposal. The MPCs are filled with spent fuel assemblies and sealed in the NPP, then, following transport to the SFISF site – in special containers designed for transporting the MPCs – the canisters are placed in a concrete storage structure built underground.

The loading and servicing of the storage canisters will essentially be accomplished in a manner similar to the technology currently used for the C30 casks to transport the spent fuel assemblies to the SFISF, supplemented by sealing the MPC by welding, draining the water from it, followed by drying the assemblies and filling in inert gas and finally sealing the openings required for these latter operations by welding and checking for leak tightness.

2.4.3. Other planned reconstructions, measures and interventions

The technical conditions for the SSLE are based on technical inspections, planned aging management activities, refurbishments, equipment and instrument replacements and maintenance work, carried out at the NPP on an on-going basis. The activities summarized below are necessary regardless of the SSLE plans but serve as the basis for their implementation at the same time. In the coming years, the replacement of several pieces of equipment will not be possible to prevent due to lack of spare parts or the wear and tear and obsolescence of the equipment.

The following equipment and instrument replacements, renovations and reconstructions have been planned for the coming years which, from the perspective of the environmental impacts were under review, fundamentally generate waste:

- Reconstruction and reinforcement of the main plant buildings, auxiliary buildings, diesel engine compartments, medical and laboratory buildings, warm-water channel and other structures.
- Replacement of reactor internal equipment, pumps, heat exchangers, fittings, compressors and filters and reconstruction work related to the spent fuel and fuel manipulation pools.
- Replacement of components in communication systems.
- Replacement, refurbishment of radiation monitoring systems.
- Replacement, refurbishment of instrumentation and control equipment.
- Refurbishment of components of the radioactive waste classification system.

- Installation of a new radioactive waste compactor press, removal of ⁶⁰Co, replacement of the complex decomposition equipment, refurbishment of the equipment of the liquid waste processing technology and periodic refurbishment of the cementation technology.
- Renovation of the fire alarm system components and replacement of the fire alarm and suppression control system components.
- Other reconstruction-related activities include:
 - replacement (or refurbishment) of the pumps in the high-pressure emergency core cooling system,
 - reconstruction of the hermetic carbon steel liners,
 - replacement and upgrade of fans,
 - replacement of the liquid nitrogen storage tanks and liquid nitrogen vaporization system,
 - replacement of the high-pressure nitrogen vaporization system,
 - elaboration of a long-term strategy regarding the emergency diesel generators for Units 1-2 (considering options for full or partial replacement),
 - replacement of transformer stations of the external distribution ring network,
 - replacement of the valves of the steam generator blowdown system,
- Renovations and equipment replacements for electrical, civil engineering services, wet utilities blocks and sewage pumping systems.
- Equipment replacements covering the chemical sampling system.
- Renovation, reconstruction and replacement of hoisting equipment; replacement of light fixtures and electric motors.

Preparations for the SSLE therefore also include the implementation of interventions required in connection with the authorized 50-year operating period. However, work falling under the scope of routine maintenance must be performed continuously even during the extended service life. This is supplemented by targeted activities required exclusively due to the SSLE.

2.5. Emissions and environmental monitoring

The Paks NPP operates in conformance with the conditions set forth in its valid environmental license. As a facility in operation for several decades, the activities conducted to monitor the condition of the environment ensure the traceability of the power plant's environmental impacts by providing detailed and up-to-date information on the condition of the environment. The operations of the NPP are also governed by regulations and procedures pertaining to environmental protection, some of which – in accordance with jurisdiction and legal requirements – are approved by the environmental protection authority.

The environmental protection measures, procedures and inspections that have been implemented and are in use are fundamentally adequate and suitable for monitoring the NPP's environmental emissions and the condition of the plant's environment during the period of the extended service life as well. In the event of future legislative changes, significant modifications to the NPP's systems or potential changes in environmental conditions, the plant's environmental protection measures, procedures and practices will be reviewed as necessary and where justified, modified or supplemented. To ensure this, the NPP operates an Environmental Management System certified according to the MSZ EN ISO 14001:2015 standard.

MVM Paksi Atomerőmű Zrt. will continue its existing environmental monitoring activities, prolonging them to cover the period of the SSLE. Due to the modifications planned in preparation for the SSLE and described in *Chapter 2.4.*, supplementing certain activities related to the monitoring of environmental emissions will also be necessary.

The most important environmental monitoring activities and measures required by the NPP's environmental license and carried out in connection with the operation of the NPP are as follows:

- Protection against radioactive radiation:
 - Assessment of radiation exposure to wildlife: sampling and gamma-spectrometric measurements conducted every 5 years.

- Gamma-spectrometric measurements of soil and Danube sediments are conducted also every 5 years.
- An emission monitoring system is operated to determine radioactive emissions. Monitoring of the power plant's radioactive emissions is conducted in accordance with the provisions of the currently valid Emission Monitoring Regulations (EmMR).
- An environmental monitoring system is in operation to monitor the environmental impacts of radioactive emissions. Environmental monitoring of the power plant's surroundings is conducted in accordance with the provisions of the currently valid Environmental Monitoring Regulations (EnMR).
- Water protection:
 - The impact of the NPP's warmed cooling water and wastewater on the water quality and wildlife of the Danube is monitored using a system that meets the requirements of the Water Framework Directive. Monitoring tests are conducted every three years in every season.
 - The plant's cooling water and the raw water used in the process water treatment plant are sourced from the Danube, the drinking water is supplied from wells in Csámpa (confined groundwater), while and the fire protection system is supplied by riverbank filtered wells. The V4 sampling point (*Figure 2.5-1.*), located in the energy-dissipating structure at the mouth of the warm-water channel serves to ensure both regulatory and self-monitoring sampling. The sampling point represents the quality of the combined discharge (mixture) of all used water and treated wastewater discharged into the Danube. (The V1 sampling point, located next to the cold-water channel continuously monitors the radiometric characteristics of the Danube while the V2 sampling point, located at the end of the warm-water channel, the radiometric characteristics of the condenser outlet, the safety and process cooling water, water from the sludge basins and rainwater pumped from the Southern Belt ditch. The combined characteristics of the treated fecal sewage discharged through the outlet pipe and the excess water are measured by the equipment at the V3 sampling point. Continuous sampling is also conducted at each sampling station for laboratory analysis. Under the current monitoring program, each parameter for which limit values are specified in the water rights permit are surveilled.
 - To protect the Danube's wildlife from thermal pollution, the temperature of the Danube water taken out for cooling and the warmed cooling water discharged (at the discharge point) is continuously measured. If the Danube water temperature at the Paks water level gauge section is expected to reach or exceed 25°C according to the daily forecast of the National Water Level Forecasting Service, compliance with the 30°C limit is verified by manual measurement at the 1525.5 river kilometer mark of the Danube.
 - The power plant operates the monitoring system established to protect the riverbank-filtered water resources of long-term significance operating in the relevant section of the Danube affected by the discharge of used water (monitoring of impacts on groundwater) in accordance with the provisions of the currently valid water rights permit. The power plant's impact on groundwater and soil is monitored using an extensive system of groundwater monitoring wells. As part of the the monitoring system 42 groundwater monitoring wells are ckecked for various parameters, depending on the technology being monitored. To track groundwater and the movement of any contaminants, water levels are recorded in 118 wells, 18 of which are equipped with automatic water level recording devices.
 - To monitor changes in the condition of the Danube riverbed and the riverbank, previous surveys are repeated every 10 years.
 - The results of the inspection program established in connection with the aging of systems classified as non-safety-related (i.e., those without nuclear or other safety functions) that pose a risk to the environment in the event of failure, along with the associated maintenance (refurbishment) schedule and the program for assessing the environmental impacts, are submitted to the environmental protection authority every five years.

- Waste management:
 - MVM Paks Atomerőmű Zrt. systematically fulfills the power plant's waste management objectives – reducing the volume and hazardous nature of the generated waste, maximizing the recovery rate of the generated waste as much as possible and further developing the selective waste collection system – taking environmental and economic considerations into account.
- Air quality protection, operation of stationary emission sources of air pollution:
 - Compliance with the emission limits for stationary emission sources of air pollutants specified in the environmental license verified every five years through standardized emission measurements conducted by an accredited measurement organization.
- Noise protection:
 - MVM Paks Atomerőmű Zrt. ensures compliance with the noise exposure limits set forth in the applicable legal regulations.

As part of preparations for the SSLE, out of the planned modifications at the NPP, the commissioning of the alternative warm-water channel section and the replacement safety diesel generator will necessitate to supplement the emission and environmental monitoring activities.

With the construction of the alternative warm-water channel section, a new water outlet point will be established from the power plant into the Danube, approximately 350 m south of the existing one, through the construction of a power-dissipating structure similar in design to the existing one. Therefore, at the new discharge point of the alternative warm-water channel section into the Danube, implementation of a new measurement and water sampling site is planned, equivalent to the water quality measurements currently conducted (V4 sampling station) before the existing warm-water channel connects to the Danube. The range of water quality parameters tested at the new measurement site and the measurement method will be identical to those used at the existing V4 sampling site. Compliance with the 30°C limit for the Danube's water temperature will be monitored at a cross-section located 500 m downstream from the new discharge point, after the commissioning of the alternative warm-water channel section.

Considering that the replacement emergency diesel generator planned for installation – like the existing emergency diesel generators – is classified as a stationary emission source of air pollution, compliance with the emission limits for air pollutants specified in the environmental license is verified every five years through standardized emission measurements conducted by an accredited measurement organization.

The fundamental task of nuclear environmental monitoring on one hand is to continuously monitor the release of radioactive materials from the power plant and, on the other hand, to comprehensively examine their presence in the immediate environment. The monitoring is two-tiered: the telemetry networks continuously measure and monitor the most important emission and environmental radiation levels, as well as meteorological characteristics, while the sensitive laboratory tests supplement and refine the telemetry results. The annual amount of continuous and, where possible, representative samples is nearly 10,000 while the number of mostly nuclide-specific data obtained through their analysis is two to three times that figure. The assessment of the power plant's nuclear environmental impact is primarily based on comparing emissions to isotope-selective radioactive emission limits.

The task of the NPP's Operational Environmental Radiation Monitoring System (ÜKSER) is to demonstrate, through direct environmental measurements, that the plant does not have an impact on the environment greater than licensed during normal operation. Radiation monitoring of the plant's environment is based partly on telemetric monitoring systems and partly on laboratory analyses of samples. *Figure 2.5-1.* shows the locations of the sampling and telemetric monitoring stations in the vicinity of the Paks NPP. Laboratory tests cover both environmental media and elements of the food chain. This involves the processing and measurement of approximately 4,000 samples annually.

To measure the dose rate of environmental gamma radiation, a dosimeter system that has undergone type testing and calibration is used at all monitoring points. The type "A" and "G"

stations are located within a 1.5 km radius, while the B24, L25 and type “C” stations within a 30 km radius around the power plant.

The determination of public radiation exposure is performed using calculation methods based on the release and dispersion of radioactive materials for the critical population group (Csámpa /atmospheric releases/ and Gerjen /liquid releases/).

The Paks NPP’s emission and environmental monitoring system is fundamentally suitable for monitoring the combined emissions of the existing Paks NPP and the under-construction Paks II NPPs. However, modifications are necessary in a few areas. To ensure adequate environmental monitoring of Units 5 and 6 of the Paks II NPP, it will be necessary to increase the number of type “G” stations supplementing the measurements of the type “A” stations, located among the type “A” stations – once the new units are commissioned.

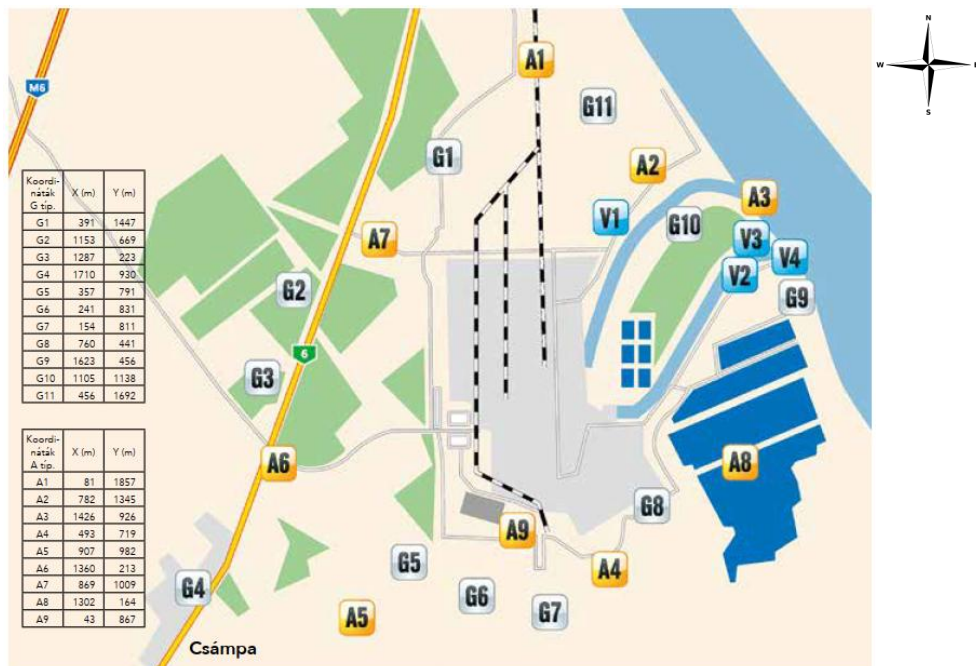


Figure 2.5-1. Location of Type “A”, “G” and “V” telemetric monitoring stations in the vicinity of the NPP

3. Current environmental impacts of the NPP and expected changes due to the SSLE

3.1. Environmental factors, impact processes

The purpose of the environmental impact assessment is to predict the changes that will occur in specific elements and systems of the environment as a result of the planned activity, compared to a defined baseline and to evaluate these changes based on the changes observed in the final impact recipients. To carry out the impact assessments, the power plant technology and the scope of related activities, along with the activities planned in preparation for the SSLE were first reviewed. Based on this, the individual environmental impact factors (e.g. material and energy emissions, waste generation, noise pollution, etc.) were identified, along with the resulting potential direct and indirect impacts, i.e., the potential impact processes.

The identification of impact factors and impact processes during the environmental impact assessment was conducted relative to the individual phases of the planned activity (construction, operation, decommissioning). In this particular case, the construction phase corresponds to the implementation of the preparatory activities for the SSLE. The operation phase refers to the 20-year duration of the SSLE. However, the decommissioning and dismantling of the NPP is,

under legal regulations, an activity requiring a separate impact assessment and therefore, the environmental impact assessment covered the assessment of the impacts of decommissioning at a theoretical level only.

Among the activities planned as part of the preparations for the SSLE, the interventions to take into account – as they represent significant environmental impact factors and therefore require detailed examination – included the construction of the alternative warm-water channel and the peak cooling system, as well as other reconstruction works affecting the NPP's mechanical, electrical, instrumentation and control systems and structures.

Activities related to the construction of the alternative warm-water channel section, the connected structures and the cooling cell system, which may appear as impact factors are:

- the land occupation required for site preparation and construction work (project buildings, storage of construction materials, structural materials and machinery and the establishment of work areas), which extends also to the protected Natura 2000 site,
- site preparation work (vegetation removal), construction and installation work (dust generation, exhaust fumes from transport and construction machinery, noise and vibration pollution, disturbance and the presence of construction personnel),
- the transport of construction materials and workers to the construction site and the removal of generated waste (dust generation, exhaust fumes from transport and loading machinery, noise and vibration pollution, disturbances and road quality deterioration),
- waste generation during construction work (municipal, hazardous and non-hazardous industrial waste),
- the appearance of new buildings on the power plant site.

Of these, the impact of land occupation – which also affects protected areas – is primarily significant, while the effects of air pollution, noise pollution and waste generation are temporary during the construction period.

The impact factor to be examined in the environmental impact assessment in connection with other reconstruction works affecting the NPP's mechanical, electrical and control systems, as well as its structures, is waste generation (municipal, hazardous and non-hazardous industrial waste, radioactive waste).

Considering that in the present case, the impact assessment pertains to the existing and operational facility, the impact factors and impact processes during operation are essentially the same under the current conditions and in the event of a SSLE. Compared to the known environmental impact factors already associated with the current operations, the noise and heat emissions into the ambient air from the forced-draft, wet cooling cell based cooling system must be considered as new impact factors. With regard to the thermal load on the Danube, the discharge of the warmed cooling water into the Danube remains the impact factor to be examined. However, the construction of the alternative warm-water channel will result in the creation of a new discharge point into the Danube. With regard to air pollutant and noise emissions as environmental impact factors, the atmospheric and noise emissions resulting from the operation of the replacement emergency diesel generators for Units 1 and 2 must be accounted for, as these represent a new source. The environmental impact factors of the NPP's operation are as follows:

- Land use and land occupation – due to the structures of the alternative warm-water channel and the peak cooling system, certain areas within the site will be developed, otherwise, there will be no changes during the extended service life.
- The existence of the facility (electricity generation activity, retention effect on the community, landscape impact).
- Operation – all impacts (radiological and conventional), emissions (impact on environmental elements, changes in quantity).
- Transportation (operating personnel, delivery of operating supplies, tools, machinery and equipment, removal of waste, which come with air pollutant and noise emissions, as well as disturbances).
- Technological water intake from the Danube (changes in the volume of surface water).

- Drinking water intake from the Csámpa waterworks (changes in the volume of groundwater).
- Cooling water intake and discharge of warmed cooling water back into the Danube (thermal load, hydraulic and hydromorphological changes).
- Discharge of sludge from the dredging of the cold-water channel into the Danube (hydrological and water quality impacts, effects on aquatic life).
- Generation and treatment of wastewater and stormwater (changes in quantity and quality in the receiver).
- Generation of wastes, interim storage on-site, transport and management (conventional and radioactive wastes).
- Generation of spent fuel assemblies.

The following are potential environmental impact factors of operational malfunctions and emergencies that may occur during operation:

- Failures of plant systems and equipment that may result in the release of radioactive and conventional pollutants into the environment (e.g. pipeline breaks, leakage of pollutants /oils, chemicals/ into the soil, or subsurface geological formations due to pipeline breaks and failures in the turbine oil system, transformers, tanks or pipelines).
- Release of pollutants into surface and groundwater and soil due to malfunctions in operational systems and equipment (improper operation of the industrial wastewater and municipal sewage treatment systems).
- Air pollutant and noise emissions during the operation of diesel generators due to loss of offsite power.
- Contamination of soil/subsurface geological formations during waste storage, handling and transport due to dispersion and spillage.
- Contamination of the geological environment resulting from malfunctions or accidents during the delivery and internal transport of hazardous materials.
- Waste generation during remediation (excess beyond normal operating conditions).

The results of the environmental impact assessment conducted with the consideration of the above factors are summarised in the following chapters, broken down by environmental impacts associated with conventional and radioactive emissions.

3.2. Conventional environmental condition characteristics

3.2.1. Impacts on air quality

In connection with the activities planned as part of the preparations for the Paks NPP SSLE, significant air pollutant emissions are expected from the construction work on the alternative warm-water channel section and the connected peak cooling system with cooling cells. The sources of air pollutant emissions from the construction of the new channel section and the peak cooling system are as follows:

- The area affected by earthworks will be one of the primary sources of air pollution due to dust emissions from the earthworks.
- The other major group of air pollution sources will be the construction machinery operating in the work area, which will pollute the atmosphere with exhaust emissions.

Based on the results of studies regarding the construction of the alternative warm-water channel section and the peak cooling system, the pollution load caused by air pollutant emissions from the construction work will remain below the limit value in the examined environment outside the installation area. The impact area of air pollutant emissions is determined by nitrogen dioxide (NO₂) emissions, the extent of which is a circle with a radius of 1,100 m centered on the emission source, comprising the installation and operational areas as well as areas outside the site. The impacts will occur in the medium term during the phase of earthwork. The intensity of the

impact will reach the burdensome level, though this will only occur in a relatively small portion of the impact area.

With regard to emissions of conventional air pollutants associated with the operation of the NPP, the sources of air pollution are the diesel generators located on the site. There are several diesel generators operating as emergency backup power sources at the Paks NPP site, whose exhaust stacks are stationary emission sources of air pollution. Under normal operating conditions, the diesel generators only operate during test runs, when they undergo a few hours of test operation per year, with only one diesel generator running at a time.

Based on the results of the atmospheric dispersion model calculations, the air pollutant emissions from the operation of the diesel generators remain below the limit value in the studied environment outside the plant site. The impact area of air pollutant emissions is defined by nitrogen dioxide (NO₂), the extent of which is a 690-meter radius around the emission source for the standalone operation of the Paks NPP and a 700-meter radius for simultaneous operation with the Paks II NPP, encompassing both the site and areas outside the site. The intensity of the impact reaches the burdensome level. However, these impacts will occur only periodically and in a relatively small portion of the impact area. It can be assumed that the operational tests of the diesel generators at the two NPPs will not be carried out simultaneously. However, for the sake of conservatism this was not taken into account in the analyses.

Another source of air pollutant emission associated with the operation of the Paks NPP is transportation related to the facility's operation, including road vehicles of various categories: passenger cars, light trucks, motorcycles and buses. Based on the results of the calculations performed, the load from pollution caused by air pollutant emissions of road traffic remains below the limit value in the vicinity of the transport routes. The impact area of air pollutant emissions is determined by nitrogen dioxide (NO₂) emissions, the extent of which is within 3 meters of the road edge along the southern access road to the Paks NPP, as well as along the section of Main Road No. 6 and along the section between the southern access road of the Paks NPP and the Paks-Kölesd Road intersection, within 20 m of the edge of the roadway. The impacts will be neutral.

When the Paks NPP and the Paks II NPP are operated simultaneously, air pollutant emissions from traffic associated with the two facilities must also be taken into account. The sources of air pollutant emissions from traffic will also be motor vehicles in various categories. Based on the results of the calculations performed, the air pollutant emissions from road traffic will remain below the limit value in the vicinity of the transport routes. The impact area of air pollutant emissions is determined by nitrogen dioxide (NO₂) emissions, the extent of which is within 30 meters of the road edge along the southern access road to the Paks NPP, as well as along the section of Main Road No. 6 and along the section between the southern access road of the Paks NPP and the Paks-Kölesd Road intersection, within 20 m of the edge of the roadway. The impacts will be neutral in this case as well.

In the event of an emergency requiring consideration in terms of air pollutant emissions, the sources of air pollutant emissions will be the exhaust manifolds of the Paks NPP's three emergency diesel generators per unit (12 in total).

Based on the results of the model calculations performed, the air pollutant emission load resulting from the operation of the diesel generators remains below the limit value in the examined environment outside the plant site. The impact area of air pollutant emissions is determined by nitrogen dioxide (NO₂) emissions, the extent of which is a circle with a radius of 1,600 m centered on the emission source, encompassing both the site and areas outside the site. The effects of the diesel generators' emergency operation occur during the emergency event. The intensity of the effects reaches the burdensome level within the impact area.

3.2.2. Impacts on meteorological and climatic conditions

In addition to analysing the meteorological factors typical to the NPP site, a forecast was prepared regarding the expected impacts of climate change, taking into account the duration of the planned SSLE. The results of two so-called RCP (Representative Concentration Pathways) scenarios

were used for the analyses (RCP4.5 and RCP8.5). RCP8.5 is a highly pessimistic, climate-policy-free scenario assuming high greenhouse gas emissions, while RCP4.5 is a more optimistic scenario in which emission reduction efforts are successful. According to RCP4.5, a national average temperature increase of 1.5-2.9°C is expected by the end of the 21st century, while according to RCP8.5, an increase of 3.5-5.3°C is expected in comparison with that of the end of the 20th century.

The climate impact of the NPP on the environment is determined by the following factors:

- The existence of the site and the so-called urban (heat island) effects resulting from built-up areas.
- The heat load resulting from the operation of the power plant:
 - heat discharge into the Danube via the fresh-water cooling system, as an indirect effect; heat transfer to the ambient air due to the higher water temperature of the Danube;
 - direct heat emissions into the ambient air resulting from the operation of the planned peak cooling system (vapor emissions from artificially ventilated wet cooling cells).

The Paks NPP and its connected facilities significantly altered the landscape when they were built. Former agricultural and biologically active areas were built-up, which significantly affected, for example, the area's albedo (i.e., the surface's ability to reflect solar radiation), evaporation conditions, and biological activity.

As a result of the difference in energy balance between built-up areas and natural surfaces, the average temperature in such areas is higher than in neighbouring areas. In the case of the Paks NPP, this difference is negligible, estimated at only a few tenths of a °C on an annual average.

Given that the Paks NPP has been in operation for decades, it can be stated that the SSLE will not trigger previously unobserved impact processes. In other words, no changes to the area's condition or functions are to be expected. The continued standalone operation of the Paks NPP will not have a significant impact on changes in the site's meteorological and climatic conditions due to the built-up character of the area, coming from the nature of the infrastructure. This will not change even as climate change progresses. However, due to general warming, the already existing, so-called urban heat island effect is expected to get more intensive.

During the operation of the Paks NPP with its extended service life, significant new construction will be represented by the route of the alternative warm-water channel section and the connected cooling cells, along with their associated equipment, structures and other facilities. This facility will be constructed largely on land, which currently has forests and fish ponds, so the size of the power plant area previously affected by urban impact will slightly increase.

With the construction of the Paks II NPP, the size of the undeveloped area with natural vegetation at the Paks site will continue to decrease, consequently the spatial dimension of the urbanization is expected to extend in the Paks II NPP area, even if climate change is not taken into consideration.

Regarding the impacts resulting from the thermal load on the Danube, it can generally be stated that heat emissions through the cooling systems of freshwater-cooled thermal power plants may cause local changes in certain climatic elements. According to the results of the measurements focused on mesoclimate effects conducted as part of the site characterization program in frame of the first service life extension of the Paks NPP, these effects are limited to the immediate vicinity of the NPP and due to the thermal load on the Danube, the narrow river valley. This is further confirmed by the fact that the results of meteorological observations having been conducted continuously since the construction of the NPP have not revealed any significant deviations in the measured parameters compared to nationwide trends.

Based on the measurements and modelling performed, it has been determined that the thermal load caused by the warmed cooling water discharged from the Paks NPP into the Danube – although detectable – does not represent a change in the atmospheric environment significant enough to warrant intervention.

With regard to the standalone operation of the Paks NPP, based on the available information, no changes in the mesoclimatic characteristics resulting from the thermal load on the Danube are anticipated during the plant's continued operation. Following the commissioning of the Paks II NPP, the thermal load on the Danube will nearly double compared to the current levels. This will obviously intensify the thermal impact, but it will not reach a level that would question the above findings. The climatic effects resulting from the thermal load on the Danube caused by the outflow of the warmed cooling water from the two NPPs are expected to be detectable locally at the power plant site and in the immediate vicinity of the warm-water channel. However, mesoclimatic changes resulting from this cannot be assumed.

The purpose of the alternative warm-water channel section and the connected peak cooling system planned for the duration of the SSLE is to reduce the temperature of the warmed cooling water being returned, in order to ensure compliance with the 30°C upper water temperature limit prescribed for the Danube cross-section 500 meters downstream of the outlet point, even with high Danube water temperatures, while maintaining the power plant's output, taking into account the operation of the Paks II NPP as well. The Paks II NPP, like the Paks NPP, will have a fresh-water cooling system, but a similar peak cooling system is planned for the subsequent cooling of the warmed cooling water along the new warm-water channel to be constructed for the Paks II NPP.

The cooling cell arrays of the peak cooling systems, however, do not operate continuously at either NPP, they are only brought online during critical periods (when Danube water temperatures are high) and gradually. On an annual basis, their total operating time is expected to be limited to short periods with summer heat waves. The peak cooling systems to be installed will emit large amounts of water vapor during operation, which is expected to affect the microclimate. With regard to vapor emissions, it is likely that they will periodically influence changes in air humidity in the vicinity of the NPPs.

The expected relative humidity in the airspace above the cooling units, even with the two peak cooling systems on maximum load and under the most unfavorable wind conditions (wind speed <0.5 m/s) will remain below 85%. Thus, even if moisture is visible locally in the airspace immediately above the cooling cells (a few tens of meters), the visible moisture from the extra moisture emission will quickly evaporate in the large air volume and will not lead to significant cloud formation. It can also be concluded that the frequency of operating conditions associated with the greatest increase in humidity is negligibly small.

Considering that operating the peak cooling systems are required during prolonged warm summer periods, when air humidity is generally low, the effect of vapor emission can be considered as positive, since it compensates for part of the evaporation deficit resulting from built-up areas during the most critical enduring warm summer periods. Its positive effect is primarily evident in the nighttime and early morning dew formation, which provides moisture that plants can utilize.

The assessment of the Paks NPP's exposure and sensitivity to climate change was conducted following the methodology outlined in the Climate Resilience Guideline (February 2022), commissioned and published by the Prime Minister's Office. The climate protection rationale for NPP SSLE is supported by the fact that, in line with energy and climate strategies, electricity generation with the NPP is an activity that results in low greenhouse gas emissions. The analysis confirmed that the facility's climate adaptation characteristics are favorable, the NPP's robust design and significant safety margins are remarkable, not only in terms of other human and natural hazards, but also from the perspective of adaptation to the effects of climate change.

3.2.3. Impacts on surface waters

3.2.3.1. *Physical and chemical characteristics of surface waters and sediments, bacteriology*

The examination and the assessment of the ecological status of the Danube and the surrounding surface waters were conducted based on the physical, chemical and bacteriological characteristics of the waters and sediments, as well as on biological components including

phytoplankton, phytobenthos, macrozoobenthos and fish communities. Zooplankton was also included in the assessment – despite not being among the biological elements required to be assessed under the Water Framework Directive (WFD) – as these communities are good indicators of the nutrient and material cycling status of aquatic environments.

Archived chemical and biological data available from 2000 to 2023 were used for the impact assessment. The purpose of analysing the archived data was to assess the long-term impacts of the Paks NPP on surface waters. To assess the ecological status, a comprehensive survey was conducted in 2024, while in 2025, a detailed ecological assessment of the impacts of environmental variables was carried out from an ecological perspective, along with an evaluation of the impacts of the alternative warm-water channel with the planned new water outlet point and the connected peak cooling system.

The purpose of the studies conducted in 2024 was to assess the ecological status of the affected sections of the Danube from the WFD perspective, to conduct an ecological analysis of individual biological elements, along with an analysis of the current impacts of the non-radioactive discharges of Paks NPP – particularly its warmed cooling water – on the water quality of the Danube and its side arms, specifically the physical, chemical and bacteriological properties of the water, as well as on the studied communities of organisms, to assess the baseline conditions under the current operations. The studies covered the main channel of the Danube between river kilometers 1544 and 1474, which belongs to two water bodies: the Danube between Dunaföldvár and the Sió mouth (AOC754) (directly affected by discharges from the Paks NPP) and the section of the Danube between the Sió mouth and the national border (AOC755) (indirectly affected by discharges from the Paks NPP via the previous water body). The assessment of biological elements was extended beyond the main channel to include one sampling section each on the four major side arms in the affected lower Danube section: The Uszód side arm, the Grébeci-Holt-Duna, the Rezéti-Holt-Duna and the Vén-Duna. The hydrological and biological studies conducted in 2025 took place on the section of the Danube near the NPP.

Among the basic chemical components of the WFD, the impact of emissions from the Paks NPP could be demonstrated with respect to two components. Based on the evaluation of the concentrations of total inorganic nitrogen and accordingly, of total nitrogen among the nitrogen forms examined, it was determined that the NPP's emissions have a minor local impact on the nitrogen cycle in the immediate downstream waters on the right bank of the affected section of the Danube nevertheless, on one hand, this impact does not result in the deterioration of water quality by one class even in the immediate vicinity of the discharge and on the other hand, factors independent of the NPP's discharge – specifically, the hydromorphological characteristics of the downstream, as revealed by ecological analyses – play a more significant role in the nitrogen cycle of this section. The discharge of the NPP's warmed cooling water clearly influenced the level of oxygen saturation in the warmed section of the Danube, in addition to the nitrogen cycle. However, this change also did not cause a class-value change in status, even in the area immediately downstream of the outlet. With regard to the other basic chemical components, no change attributable to the NPP's discharge was detectable based on a detailed evaluations of the sampling sites.

According to the chemical status assessment based on the WFD criteria using the groups of basic chemical components, the 2024 study indicated excellent chemical status for all element components across all eight sections examined.

However, based on the specific pollutants evaluated, it was determined that of the eight sections of the Danube examined, only lead met the criteria for good chemical status. For arsenic, zinc, chromium, copper, cadmium, mercury and nickel, water quality at one, or more points did not meet the limit values for good status specified in the River Basin Management Plan (RBMP3). The detailed analyses, however, revealed that the inadequate chemical status observed in the sections cannot be related to emissions from the Paks NPP. The source of the excess values observed in the immediate downstream area is located upstream of the city of Paks. The likely cause of the pollution indicating the extreme values is a one-off or periodic discharge of wastewater with high concentrations.

The discharge of warmed cooling water from the Paks NPP into the Danube clearly represents the most significant impact in terms of thermal load. As a result of the discharge, the maximum temperature increase at the sampling site on the right bank of the warm-water outlet was 9.6°C during the May sampling period of the 2024 studies. Analysis of the water temperature data revealed that the temperature decrease toward the downstream section is significant even in the short term, measured at the right-bank sampling point at Nagy-sarkantyú (1525.3 river km), this decreases averaged 6.5°C. Subsequently, the rate of temperature decrease gradually decelerates and distributes over a greater spatial area.

Consistent with the results of model calculations conducted to examine the thermal load on the Danube, the studies confirmed that the warm water plume propagates along the right-bank of the Danube. Furthermore, the model results and the study findings indicate that the spatial distribution of the thermal plume is influenced both by the river's flow rate and flow conditions. A critical condition in terms of thermal load is the combined occurrence of high ambient temperature and low flow rate.

Based on chlorophyll-a, the studied section of the Danube fluctuated between oligotrophic (nutrient-poor) and mesotrophic (moderately nutrient-rich) conditions throughout the year. The evaluation of the seasonal variation in chlorophyll-a shows that it reaches its annual maximum as early as April. The Danube during this period is already in the mesotrophic state. Samples from May and August showed concentrations very similar to those in April. By October, the chlorophyll-a concentration decreases significantly along the entire stretch. At this time, the Danube water could be classified as oligotrophic at all measurement points.

Analysis of the water's oil derivative content (TPH-GC) indicated occasional, minor and localized impacts from the Paks NPP. The single, elevated TPH value observed at the discharge point did not cause a class level deterioration in water quality at the sampling site, nor did it extend to the area of the subsequent sampling section. Nevertheless, the increase in polycyclic aromatic hydrocarbon (PAH) concentrations observed at the sampling site on the right bank of the warm water outlet during sediment analysis confirmed this temporary power plant impact.

In addition to the parameters presented above, the assessment program also included the analysis of other chemical components (total suspended solids, alkalinity, iron, manganese, sodium, potassium, magnesium, calcium, carbonate, bicarbonate, total hardness, sulfate). Impact of emissions from the Paks NPP could not be detected with regard to these components.

The bacteriological tests indicated that the colony counts of Coliform and fecal Coliform bacteria, as well as of *Pseudomonas aeruginosa*, showed significant seasonal variations. Typically, the May and October samples had the lowest counts, while the August sample had the highest, often showing an order of magnitude higher. In this phenomenon, in addition to water temperature, the river flow rate may also play a role. Based on fecal contamination findings, the impact of the Paks and Kalocsa-Baraka wastewater discharges (Gerjen), as well as the confluence of the Sió River in the lower section, was particularly evident during the summer months. Unlike fecal bacteria, the population counts of *Salmonella*, psychrophilic and mesophilic bacteria and *Clostridium aeruginosa* did not show significant seasonal variation. No trend-like distribution along the longitudinal profile was observed in any of the studied groups. Based on the evaluation of the sampling sites, the impact of emissions from the Paks NPP was also not detectable for any group of bacteria.

Analysis of 96 phytoplankton samples collected during four sampling occasions (April, May, August, October) in 2024 along the studied section of the Danube confirmed the presence of a rich microflora. The floristic composition corresponded to what is generally observed in large, lowland, slow-flowing rivers, i.e., a high proportion of diatom and green algae taxa is evident. It was found that the number of species occurring in all samples was low, with the vast majority of species consisting of sporadic elements that appeared in less than 5% of the samples.

The results of studies conducted in 2024 confirmed that the Danube's phytoplankton exhibits characteristic seasonality in terms of biomass, with high biomass in April followed by a decline in biomass, resulting in oligotrophic conditions by autumn. However, no drastic changes occur in the composition of phytoplankton. The minor changes observed in dominant taxa did not affect the river's ecological status.

The impact of thermal loading was assessed by examining the background variables and microflora of clearly distinguishable study sites (control, directly affected and directly not affected). Based on this, it was clearly confirmed that the load has no detectable significant effect on the phytoplankton communities of the Danube.

The side branches connected to the Danube form two groups based on their phytoplankton dynamics and composition. The Uszód branch and the Rezéti-Holt-Duna, which maintain a living connection with the Danube, as well as the Vén-Duna, possessed plankton with similar biomass in a composition nearly identical to that of the living river. The more isolated Grébeci-Holt-Duna clearly exhibited a lake-like character, in terms of both its quantitative conditions as well as its dynamics and composition. No differences in phytoplankton composition or abundance attributable to the thermal loading were observed in any of the branches.

Sampling of periphytic diatoms (phytobenthos) was conducted in 2024 at the designated 8 sections, at a total of 16 sampling points (one on the right and one on the left side of each section), on three occasions (May, August, October). The structure and species richness (number of taxa) of the periphytic diatom community showed no spatial separation; no statistically significant differences were detected either in terms of sampling location, or impact. At the same time, natural seasonal differences were evident.

Based on the diatom index values at the sampling sites, it was determined that at locations directly affected by the warm water discharge, the annual average values indicated a moderate condition, while at the sampling site, moderate and good ratings occurred with equal probability.

However, based on the annual average EQR (Environmental Quality Ratio) values, there was no significant difference between the two water bodies studied. In contrast, the annual average rating of the section directly affected by the warm-water discharge was significantly lower than that of the control (upstream sampling sites and left-bank sites up to Uszód) and the sections considered as unaffected (Gerjen-Baja). The rating values demonstrate the local impact of the warm-water discharge. At the same time, river groynes in the affected section disrupt the riverbed's alignment and the resulting decrease in flow velocity at these points causes microhabitat-level changes. Additionally, on a micro-scale, the water's physical and chemical parameters may differ – albeit to a small extent – from those of the main channel. The formation of these combined conditions creates favorable conditions for the local enrichment of species associated with slow-flowing waters and/or elevated conductivity and trophic status, primarily, though not exclusively, limnophilic species. The discharge of warmed cooling water may amplify these local effects.

With the exception of the Rezéti-Holt-Duna, found in good ecological status, the studied branches are in moderate condition. However, no significant difference can be detected based on the phytobenthos-based assessment of these branches. Likewise, no statistically significant difference was detected among the branches based on their community structure. At the same time, from a biological perspective, the Grébeci-Holt-Duna's deviation from the results of the other branches clearly indicates its more enclosed, stagnant-water character. The seasonal analyses do not indicate any clear trend-like change in the phytobenthos structure and classification of the branches. No impact related to the discharge of cooling water from the Paks NPP could be detected in the branches, not even in the Uszód branch, which is the closest to the discharge point.

Quantitative zooplankton sampling was conducted in 2024 at a total of 24 sampling points across 8 sections of the Danube during four periods. In addition to the main channel, studies were also conducted in the four branches. The results of the sampling were suitable for the ecological characterization of the Danube and the four branches with different habitats, as well as for the ecological assessment of the discharge from the Paks NPP.

Based on multivariate statistical analyses of the community structure and the environmental background variables, it can be consistently concluded that the zooplankton community is primarily organized according to seasonal effects. In addition, water flowrate and the resulting changes in chemical characteristics represent a significant community-organizing force. Although temperature strongly influences community structure as well, it reflects on seasonal differences rather than on the discharge. The impact of warmed cooling water was not detectable based on

ecological analyses. The environmental and biotic characteristics of samples directly affected by the discharge did not differ significantly from those of the control sites or sites directly not affected. Among the examined oxbow lakes, the Grébeci-Holt-Duna differed more significantly from the zooplankton of the other oxbow lakes in terms of individual counts. This condition is explained by the oxbow lake's stagnant water nature and its correspondingly higher productivity. Based on the zooplankton communities of the oxbow lakes, they indicate a mesosaprobic condition.

Based on the studies, it can be concluded overall that the discharge of cooling water from the Paks NPP has no detectable impact on zooplankton communities.

The study of macroscopic aquatic invertebrates (macrozoobenthos) was conducted in 2024 at eight sections along the Danube between Paks and Baja on three sampling dates (May, August and October). Quantitative sampling was conducted at a total of 16 Danube locations (on the left and right banks of 8 sections) and 4 branches in accordance with the Hungarian WFD methodological protocol.

A total of 67 taxa was possible to identify during the surveys; the species composition well reflects the stable macroinvertebrate community characteristic of the middle section of the Danube. Four protected species were identified within the scope of the study. *Unio crassus*, the unique indicator species designated for the Tolna Danube (HUDD20023) Natura 2000 site for macroinvertebrates, was not found in 2024. In the surveyed section, it was last observed in 2015. *Anisus vorticulus*, the indicator species for the Gemenc (HUDD20032) Natura 2000 site, was also not found. The proportion of non-native and invasive species was high; 25% of the identified species belong to this group and they accounted for approximately 40% of the total number of individuals.

Species richness and population density showed high spatial variability among the sampling sites. The differences between the control sites and those affected by the warmed water discharge were statistically significant for several community indices. The responses of the communities manifested primarily not in the decline in species richness, but in a rearrangement of dominance and abundance relationships. Based on multivariate statistical analysis, water temperature had the most significant effect on the community structure. In particular, the sampling site on the right bank downstream the warm-water discharge showed a striking deviation, where the community structure was strongly associated with the environmental factors linked to the outlet - indicating that thermal load has a clearly detectable community-shaping effect here.

In addition to the 2024 study, a supplementary survey was conducted in 2025 in order to improve the ecological assessment. The results of the two studies essentially reinforce each other, but they also clarify the effects of environmental factors actually influencing macrozoobenthic communities in several respects. An increase in dominance was observed in areas affected by the warm water discharge. The studies show that the water temperature and the excess temperature are among the factors influencing community structure, but their effects are distinctly habitat-dependent. This suggests that the effect of thermal load manifests itself in conjunction with bed alignment and flow conditions. The 2025 results also support the habitat and context-dependent nature of thermal load along finer gradients of space and temperature. In ecological terms, warm-water discharge does not cause the collapse of the affected community. However, its impact is detectable locally at the level of certain community and indicator metrics.

Based on community-level threshold analyses for the year 2025, a range of change around a temperature difference of approximately 2.1°C can be identified that reflects the beginning of community reorganization. This indicates that even with a relatively small temperature increase consistent community shifts can be observed, though these shifts do not occur uniformly across all habitat types. The effect of the thermal gradient is primarily evident in areas of fine-grained substrates with low flow and limited mixing, while its impact is more moderate in habitats with coarser substrates and faster flow.

The ecological status assessment from the perspectives of the WFD indicates that the ecological status of the water body between Dunaföldvár and the Sió-mouth is moderate based on macrozoobenthos, while the water body between the Sió-mouth and the national border is in poor condition.

Among the branches, the Grébeci-Holt-Duna proved to be the richest in species (44 taxa), while the Uszód side branch showed the lowest number of species (26 taxa). Based on the results, the communities of the branches were well distinguished from the main channel samples, particularly in the case of hydrologically isolated habitats (e.g., the Grébeci-Holt-Duna). The results confirm that the degree of hydrological connectivity plays a decisive role in the diversity and structure of the communities.

The survey on the fish community was conducted in 2024 at a total of six sections using quantitative sampling in accordance with WFD criteria. Field surveys were conducted in the riparian (shore) region of each section using an electric sampling device (ESD), while in the medial (open-water) region, an electrofishing gear (EG) was used as a supplementary survey for benthic species. In addition, supplementary surveys were conducted in 2025, primarily to better understand the expected impacts associated with the discharge from the alternative warm-water channel section.

During the 2024 ichthyological survey, a total of 11,254 individuals of 44 species were identified in the Danube. A total of 34 species were found in the branches. The species composition of the surveyed sections is essentially homogeneous and, when compared with the results of previous surveys, shows a high degree of similarity. At the same time, while the populations of some species fluctuated in the past two decades, the occurrence frequency of several species has changed significantly. The 2024 study also confirmed that there is no species that cannot find suitable living conditions in the affected section due to the discharge of the warm water.

The fish species composition of the studied oxbow lakes shows fundamental similarities to that observed in the main channel of the Danube. However, depending on the stability and strength of their connection to the main channel it differs from it to a smaller, varying extent.

During sampling, a total of 3 highly protected and 7 protected species were detected at the Danube sampling sites. Five of the species under nature conservation protection were found in the oxbow lakes. Here, the protected species that prefer flowing water occurred only in those oxbow lakes which retain a more permanent connection to the Danube. Of the 11 indicator fish species in the Tolna Danube Natura 2000 site, 8 were found during sampling. Of the 12 indicator fish species in the Gemenc Natura 2000 site, the presence of 9 was confirmed at sampling sites in the main river channel.

Based on the current and past studies of the Danube, it can be clearly concluded that the natural value of the studied section of the Danube is significant, considering both the number of protected fish species found here and, even more so, the structure of the fish community. Stable populations of the most protected, fast-flow water species are present in these sections of the Danube. Among invasive species, the population of gobies continues to dominate the main channel of the Danube. In addition to these, the successful spawning of the silver carp and its increasingly vigorous invasion have also been recorded in the studied section of the Danube. The branches serve as important spawning grounds in the Gemenc section of the Danube, but they also contribute to the release of several invasive species.

Based on the 2024 surveys, among the community structure indicators, the distribution of species is homogeneous across the entire studied section of the Danube, during both the summer and autumn survey periods. Based on the results of the surveys, it was found that the number of individuals is typically higher in the sample sections directly affected by the discharge. However, no statistical difference can be demonstrated among the individual sections. The analysis of sample subunits directly affected by the warm-water discharge and those not affected, however, indicates a difference even in a statistical sense.

The findings of the community structure analyses from the supplementary studies conducted in 2025 confirm the results obtained in 2024, while refining them at the same time. It was found that fish abundance increases in areas affected by discharges from the Paks NPP. This increase causes a significant difference in areas with paved bottom that provide a homogeneous substrate, while this effect is not as pronounced in areas with natural substrates. At the same time, this also demonstrates that the composition of the substrate has a significant community-organising effect beyond temperature or more precisely, the extent of the thermal step. Based on the results, it was also determined that the thermal load is well reflected in the seasonal distribution of individual

counts. In autumn, higher individual counts are typical of areas affected by the warm water – regardless of the substrate. Water level also influences the effect of thermal load; during low-water periods, greater differences are observed between affected and unaffected sections.

The results confirmed that in areas affected by the discharge, both in the riparian and open-water regions, the water temperature elevated by the discharge has a significant impact on the structure of the fish community. In addition to the effect of warmed cooling water, the impact of substrate composition and the community-organizing effect of the flow can also be detected. Based on the studies, it appears overall that the effect of thermal load acts in conjunction with hydromorphological environmental factors, in which substrate type is a determining factor. Artificial stone pavements provide a particularly important habitat for invasive species, which, in synergy with the thermal load, further contributes to the spread of these species in the affected section of the Danube. At the same time, this result highlights the importance of maintaining habitats with natural substrates to achieve good ecological status in the Danube.

The results also highlighted the fact that the impact of the discharge is not constant in either time or space, but decreases in a gradient-like manner, meaning that the area of the observed impact is local. On one hand, the impact cannot be detected at the study sites on the left bank of the river, while on the other hand it typically does not extend onto the entire area of the studied downstream sections at the study sites on the right bank either. The survey results confirm that in the medial (open-water) region, the extent of the impact is comparable to that observed in the riparian (bank) area.

The results of the analysis of functional characteristics indicated that the fish communities of the studied branches differ to varying degrees from those of the main channel, in close correlation with the strength of their connections to the Danube. Although the fish communities of the six studied sections of the main channel are similar, minor differences can be observed among them. In the section directly affected by the discharge, flow-preferring, benthic fish species dominate, while in the lowest section, due to the influence of the Gemenc branch system, a more diverse fish community is typical, with an increase in the proportion of flow-avoiding (stagnophilic) and aquatic vegetation-associated (metaphytic) species beside flow-preferring ones.

The ecological classification under the WFD indicates that the six examined sections of the Danube at Paks range from moderate to good status, with no significant differences in the status of the individual sections. Overall, the status of both water bodies under study is good, based on the evaluation of the samples collected in the summer. The above assessment also confirms that, according to the classification based on the WFD criteria, the warm-water discharge from the Paks NPP has no detectable impact on the fish community at the scale of the water body.

The ecological status assessment of the branches shows that the three more open oxbow lakes are in good condition or very close to a good rating. The Grébeci-Holt-Duna, which is the most enclosed, has the poorest quality. Based on the assessment, the impact of the Paks NPP's discharge could not be confirmed in any of the oxbow lakes.

3.2.3.2. Assessment from the perspective of the Water Framework Directive

In the course of the studies conducted in 2024, the impact of the Paks NPP's warmed cooling water on the ecological status of the Danube was assessed based on an analysis conducted in accordance with the criteria of the Water Framework Directive (WFD). The assessment of the chemical status extended beyond the basic chemical component groups to include the examination of metals among the specific pollutants. The Zooplankton-based water quality assessment is currently not part of the biological classification systems officially adopted by the Water Framework Directive therefore, the classification of this taxon was based on expert estimation, taking into account the previous saprobity index.

As a result of the 2024 studies, the ecological status of the Danube water body designated as the Dunaföldvár-Sió-mouth (AOC754) is overall moderate. Based on expert estimates, the zooplankton is beta-mesosaprobic, indicating good status. Among the specific pollutants examined in the water body, arsenic and chromium did not meet the annual average environmental quality limit.

The ecological status of the water body designated as the Danube between the Sió-mouth and the national border (AOC755) is poor. In this section, this status is determined by the macrozoobenthos classification. However, it must be noted that the status of the water body, as determined by macrozoobenthos, is on the borderline between moderate and poor. Based on expert estimates, the zooplankton in this water body is also beta-mesosaprobic, indicating good status. Among the specific pollutants examined in the water body, arsenic, chromium, cadmium and nickel did not meet the annual average environmental quality limit values.

Based on the assessments, it can be concluded that the impact of the Paks NPP is not detectable at the water body level. That is, the plant's emissions do not cause any adverse effects on the directly influenced Danube water body between Dunaföldvár and the Sió-mouth, nor in the more distant, indirectly influenced Danube water body between the Sió-mouth and the national border.

Based on the chemical assessment, the analyses of the community structure of individual organism groups and ecological status assessments, changes of varying magnitude and direction were observed over the past approximately 20 years. Among these changes, the decrease in the nutrient loading in the Hungarian section of the Danube is noteworthy, which has resulted in a decrease in phytoplankton biomass and consequently, an improvement in the ecological status of planktonic algae. However, the climate change drives adverse changes due to rising water temperatures and an increase in the duration of extreme low-water periods. These environmental changes are continuously eroding the structure of natural communities. The spread of invasive species, particularly macrozoobenthos and fish along the entire Hungarian section of the Danube can largely be attributed to this. Based on the results of the analyses, hydromorphological conditions have not improved in the studied sections. However, together with the changes caused by the climate change, they also have an adverse effect on the status of individual organism groups. This can be linked to the deteriorating ecological status of the phytobenthos, as well as the stronger periodic fluctuations observed in the ecological status of taxa sensitive to hydromorphological conditions (phytobenthos, macrozoobenthos, fish). At the same time, it can be stated that the changes in the ecological status of the studied sections of the Danube over the past two decades are not attributable to emissions from the Paks NPP, but rather to regional-scale changes in the environmental condition of the Danube. An evaluation of archived data and the results of the studies conducted indicate that, provided that the current emission regulations remain in place, no water body-level impacts attributable to the operation of the Paks NPP are expected during its continued operation. The extended service of the NPP does not endanger the achievement of good ecological status in the affected section of the Danube.

3.2.3.3. *Impact assessment of the Paks NPP SSLE*

In connection with the SSLE of the Paks NPP, the environmental impact assessment regarding the chemical and ecological status of the Danube and other surrounding surface waters covered by the WFD identified the potential factors, the expected impacts as well as the nature of the impacts and those under impact. All potential factors that could reasonably arise in connection with SSLE were listed. At the same time, the assessment naturally focused exclusively on factors that actually affect the ecological status of the Danube.

During the impact assessment, the nature of the impact was determined applying a living-organism-centered approach – that is, by examining it from the perspective of aquatic organisms, yet also including humans as affected parties – based on its persistence, severity and significance.

The impact evaluation was prepared through the unified evaluation of available archived data, the results of measurements and analyses conducted within the framework of the 2024 studies and the results of supplementary studies carried out in 2025 to address specific questions.

In addition to examining the main channel of the Danube between Dunaföldvár and Baja (river km 1544-1474), the impact evaluation also covered four Danube branches (the Uszód side branch, the Grébeci-Holt-Duna, the Rezéti-Holt-Duna, the Vén-Duna), as well as several lake-like water bodies based on archived data (the Faddi-Holt Duna, the Northern Tolna-Holt-Duna, the Southern Tolna-Holt-Duna and the Bogyzislói-Holt Duna). The impact assessment and the

determination of the impact area were prepared by considering multiple scenarios: the current operational status of the Paks NPP, the period of SSLE and the joint operation with the Paks II NPP, as well as the operation of the alternative warm-water channel section and the connected peak cooling system during joint operation with the Paks II NPP.

The water withdrawal by the Paks NPP from the cold water channel, as well as the discharge of the warmed cooling water to the right bank of the Danube at 1526.2 river km and the treated non-radioactive process and municipal wastewater also returned via the same channel cause hydromorphological changes, an increase in water temperature and further changes in the water quality in the Danube. Based on ecological analyses of biological groups conducted in-depth with a fine resolution, the temperature increase, due to the discharged cooling water and the hydromorphological changes do have a direct, detectable impact on the structure of the community. At the same time, changes in individual chemical components – based on the assessments, the inorganic nitrogen forms, as well as oil derivatives and polycyclic aromatic hydrocarbons – do not have a detectable effect during discharge on the ecological structure of aquatic organisms. Based on this, the following actual environmental factors and direct impacts can be identified in terms of the current operations: the hydromorphological impact of water withdrawal, the thermal load from the discharge of warmed cooling water and the hydromorphological impact of the discharge of warmed cooling water.

Ecological studies have confirmed that, among the studied groups of organisms, the actual recipients of the impacts are the benthic diatoms (phytobenthos), the macroscopic aquatic invertebrates (macrozoobenthos) and the fish.

The most significant impact is the thermal load on the Danube caused by the discharge of warmed cooling water from the warm-water channel(s). The detection threshold for this impact on the affected organism groups in the Danube is Δt (thermal gradient) $\geq 2.5^\circ\text{C}$. At the same time, a significant and lasting restructuring of the community structure can be expected from a sustained temperature difference of $\Delta t \geq 4.3^\circ\text{C}$. Based on ecological analyses, the effect of absolute temperature could also be determined from the perspective of fish. In the case of critically high Danube background temperatures, experience shows fish avoidance at a downstream water temperature of $t_{\max} \geq 36^\circ\text{C}$. In line with thermal load models, it can be stated that the effect of thermal load does not extend across the entire cross-section. The effect of thermal load is typically long-term and significant, thus representing an overall burden for affected groups within the impact area.

The hydromorphological impact of the discharged cooling water is also significant, resulting in part from the discharge itself and in part from the flow-modifying effect of the river groynes constructed downstream of the discharge point. Water velocity increases at the tips of the groynes, while behind the groynes backflow while between them areas of slower flow develop. Another cause of the hydromorphological impact, related to flow velocities, is the alteration of habitat conditions, specifically changes in substrate composition. The groynes have a homogeneous stony substrate, while in the backflow and slower-flowing areas, a significant accumulation of finer-grained sediment (sand/silt) can be observed. All of these changes have significant community-organizing effects on both benthic plant and animal organisms (phytobenthos, macrozoobenthos) and fish. Analyses have confirmed that the effects of thermal impact and the hydromorphological changes reinforce each other. For this reason, this impact is fundamentally long-term, moderately strong and moderately significant in the scenarios examined. From the perspective of the affected organisms, the change in the impact is burdensome. In this regard, the impact of loading the sediment from the dredging of the cold-water channel into the right bank of the Danube must be specifically highlighted. In this case, due to the accumulation of sediment with a finer grain size, further changes in the habitat conditions can be anticipated in the slow-flowing areas between and behind the groynes, – especially in the habitats of the downstream section considered as critical – over a length of approximately 3 km. The impact of the warm water discharge is expected to be significantly amplified by the loading of Danube sediment into the right-bank area during the discharge period. The deposition of finer-grained sediment in the estimated deposition areas will significantly degrade habitat conditions for benthic organisms for periods of unpredictable duration. With loading dredged sediment

material into the Danube, pollutants bound to suspended matter (heavy metals) may accumulate in the filter-feeding organisms of the area. Based on the above, the discharge of sediment from the dredging of the cold-water channel into the right bank of the Danube – noting that this can only be interpreted in conjunction with the discharge of warmed cooling water – can be assessed as a long-term, significant and burdensome impact.

The hydromorphological impact of water withdrawal is smaller than that of the discharge; it primarily affects the impacted biological communities through changes in the Danube's riparian habitat conditions (bank reinforcement) in the vicinity of the water intake plant structures. The hydromorphological impact of water withdrawal can thus be assessed as a long-term effect in all the examined scenarios, but it is of minor significance and therefore, in total, has a tolerable impact on the affected aquatic organisms.

Based on the ecological analyses, it can be concluded overall that the environmental impact of the examined operating conditions differs fundamentally within their respective impact areas.

The impact area of water withdrawal is similar in virtually all scenarios, approximately 500 meters and extends to the right bank area between the cold-water channel and the warm-water channel, specifically the slope reinforcement. The impact area increases only with the commissioning of the alternative warm-water channel section, as in this case, during its operation, the hydromorphological impact extends to the new water discharge point over a length of approximately 850 m.

The hydromorphological impact area of the discharge varies only slightly across the different scenarios, with its effects typically extending to the vicinity of Nagy-sarkantyú.

The impact area of the current thermal load during critical low-water conditions is nearly 8 km, while during the period of the SSLE, this is expected to increase only slightly – by a few hundred meters – during the standalone operation of the Paks NPP. The case with the most significant impact and thus the largest impact area studied is the combined operation of the Paks NPP and the Paks II NPP during the SSLE period. From the perspective of the Danube's affected biological groups, the area of detectable impact in this scenario, based on thermal load model calculations on the Danube's low-water critical condition and up to the end of the service period, extends to the right-bank region up to where the Danube river reaches its 1,508.9 river kilometers, at the elevation of Fadd, 17.3 km from the discharge point. The smallest impact area is expected during the operation of the alternative warm-water channel section; its extent does not reach 2 km downstream in the right-bank water areas. The scenario with the strongest impact is the combined operation of the Paks NPP and the Paks II NPP.

Upon examining and evaluating the discharges from the Paks NPP, the discharge of untreated wastewater into the Danube resulting from a malfunction of the plant's wastewater treatment facility can be considered a rational factor in the event of an emergency affecting surface waters.

The current discharge of treated wastewater from the Paks NPP's own wastewater treatment plant is approximately 300 m³/day. Among the emergency scenarios, the impact of this was therefore examined, taking into account a one-day operational failure and calculating based on a flow rate of 300 m³/day. The methodology for the hydrological studies was provided by two- and three-dimensional hydrodynamic and dispersion models developed within the framework of the impact assessment. Actual data on the raw wastewater entering the NPP's wastewater treatment plant were used to evaluate the chemical characteristics of the load occurring during the examined emergency event. Based on the calculations performed, it was evident that the concentration of the chemical components in the wastewater discharged into the warm-water channel and subsequently into the Danube is so low – even in its untreated condition – due to the mixing that it is largely below the limit of detection.

3.2.4. Impacts on groundwater and the geological environment

The impact assessment covered the environmental condition of the groundwater in the Danube Valley within the broader vicinity of the Paks NPP, the geological and hydrogeological conditions of the plant site and the forecasting of environmental parameters for the subsequent service period. The study also aimed at documenting and classifying the condition of the water bodies

under investigation and analysing the environmental impacts associated with the SSLE, with particular attention to the thermal load on groundwater and the evaluation of the physical and chemical characteristics of the water, taking into account the standalone operation of the Paks NPP and its concurrent operation with the Paks II NPP. Local and regional examinations were conducted to carry out all these tasks.

3.2.4.1. Local and regional examinations

In frame of the local examination, the contamination of the subsurface geological formations within the site was assessed based on archived data (2006-2025), while the condition of the shallow groundwater was assessed based both on archived (2011-2024) monitoring results, as well as on the quarterly accredited groundwater sampling and laboratory test results from 2024. In addition, two types of model examinations were conducted to predict the impacts. On one hand, the local hydrodynamic and dispersion model partly designed to examine the effect of the already constructed diaphragm wall surrounding the planned buildings of the Paks II NPP and partly to examine the dispersion of any contaminants that might enter the subsurface geological formations and groundwater. On the other hand, the objective of the human health and environmental risk assessment modelling was to examine oil contamination entering the subsurface geological formations and groundwater during a potential emergency event, using a selected scenario related to the operation of the NPP that could occur in the future, based on the actual emergency event that occurred in 2024.

During the assessment, accredited sampling was conducted on a quarterly basis in 2024 from a total of 20 monitoring wells involved in the Paks site monitoring program which concluded that the on-site, local parameters of the groundwater samples indicate that the water chemistry falls within the natural range of the area.

The pollution status of shallow groundwater was assessed based on the limit values (Contamination Class B) set forth in Joint Decree 6/2009. (IV. 14.) KvVM-EüM-FVM on the limit values relevant to the protection of the geological environment and groundwater against pollution as well as the measurement of such pollutants. The results of the accredited water sampling analysis conducted in 2024 showed that, in the case of some wells, the ammonium, nitrate, molybdenum, arsenic, zinc, nickel, cobalt and lead exceeded the relevant limit values, while no concentrations above the limit values were detected for hydrocarbon derivatives. The trends from 2011 to 2024 show that the concentrations are decreasing in case of the most pollutant components.

Based on the monitoring results from 2011 to 2024 as well as on the results of the 2024 accredited sampling series, the areas affected by groundwater contamination were separated. Metal components (cobalt, arsenic, nickel, lead, zinc and copper) exceeding the (B) contamination limit are typically found in the vicinity of the industrial sludge space. The presence of arsenic above the limit value is of geological origin. Nitrate and ammonium concentrations exceeding the contamination limit occur in the vicinity of the industrial sludge ponds, the sewage canal and the makeup water treatment plant. The concentrations of most components exceeding the pollution limit are steadily decreasing. The concentration and distribution of components exceeding the contamination limit are not significant and their impact is tolerable.

The condition of the subsurface geological formations was assessed based on archived data sources. The assessment of the condition of the subsurface geological formations at the Paks NPP site was prepared based on event investigation reports from 2006 to 2024. All four contamination incidents were resolved through rapid and effective remediation, and the contamination did not spread further. Contamination of the geological environment occurred only during events of emergency.

The spread of any contaminants that might enter the groundwater was assessed by modelling tritium contamination resulting from technological malfunctions that occurred at the site earlier (around 2005). The reason for this is that tritium is a conservative tracer, meaning that the area of impact of any contaminant that may enter the subsurface geological formations or groundwater can only be smaller than that of this material. According to monitoring data, the tritium

concentration in groundwater has shown a significant decrease due to the liquidation of sources and the effect of the half-life; in several wells, it is close to the natural background level (<8 Bq/l). According to the hydrodynamic and dispersion model calculations, the tritium plume will decrease below background levels in 4-10 years during low water, in 6-20 years during medium water and in 9-25 years during high water situations.

No significant contamination of groundwater or subsurface geological formations is possible to reveal during normal operation. The concentration of tritium is continuously decreasing and approaching the background value. The tritium activity values vary depending on the water flow conditions of the Danube.

Due to the expected interventions associated with preparations for the continued operation, the impacts on the geological environment will primarily result from structural disturbances (landfilling and soil movement during the construction of the alternative warm-water channel section and the peak cooling system), but these will be localized and will not significantly affect the hydrogeological system. Changes in groundwater are minimal, and no spread of contaminants is expected.

Neither the standalone operation of the Paks NPP nor its operation concurrent with the Paks II NPP will cause significant changes in groundwater conditions. The diaphragm wall and structures surrounding the Paks II NPP site may locally alter the flow paths, but the alteration is negligible at the system-wide level.

The models developed during the studies relate to the period from 2032 to 2058. They cover the flow-modifying effects of the deep-foundation structures and the planned expansion of the cold-water channel – related to the construction of the Paks II NPP – as well as the presentation of temporal changes in tritium load distribution. The results indicate a continuous, long-term decline in tritium load, showing that even under the most unfavorable scenario, the load will fall below the natural background level (8 Bq/dm^3) within a 10-year period. The results of the studies also suggest that flow-modifying effects caused by the Paks II NPP facilities are not detectable within the Paks NPP site.

Previous emergency events (between 2006 and 2024) were typically completely resolved through rapid intervention. The incident involving oil contamination that occurred in 2024 was examined as a representative emergency case. The human health and environmental risk assessment concluded that indirect contact with the contaminated subsurface geological formations in the study area, does not exceed the acceptable human health risk level ($=1$) for the exposures and contamination examined.

The contaminant under investigation spread to another environmental component, groundwater, but no lasting environmental damage occurred. Following remediation, contaminant was no longer detectable in either the subsurface geological formations or the groundwater. All of this confirms that, provided the Paks NPP's procedures are adhered to and the required monitoring tests are conducted, only local contamination within the site can occur, which can be detected in a timely manner and prevented from spreading.

A regional assessment and study were also conducted to characterise the likely impacts of the Paks NPP SSLE. From a hydrogeological perspective, the bank-filtered water flow system is the most sensitive to the continued operation of the Paks NPP and the concurrent operation of the Paks II NPP therefore, it was necessary to examine, not only the regional groundwater flow systems, but also the connection between the Danube and the groundwater. To this end, it was necessary to assess the changes and trends in the Danube's water levels, water flow and temperature, as well as the quality, quantity and pressure conditions of the groundwater as well as the potentially affected operational and prospective drinking water resources. Subsequently, considering the typical parameters and trends necessary for conducting the impact assessment, regional hydrodynamic and local heat transport models were developed and a calibrated baseline condition was determined. The impacts were evaluated and their magnitude quantified relative to the baseline condition.

The study (model) area covers the section of the Danube between river kilometers 1534 and 1498, which is essentially a flat landscape with a gently undulating surface. The monitoring

system included on-site, bank-filtered, main network and public waterworks wells. The monitoring results were evaluated based on the limit values set forth in Joint Decree 6/2009. (IV. 14.) KvVM-EüM-FVM (pollution class B), as well as on the limit values specified in Government Decree 5/2023. (I. 12.) on drinking water quality requirements and inspection procedures. In a few cases, limit values were exceeded (in terms of sulfate, toxicology and bacteriology), which were typically dedicated to flood conditions. The continuous measurement data from the monitoring system do not indicate any phenomenon attributable to the NPP that would have led to an increasing decline in groundwater quality during the operating period. The water chemistry, microbiological and toxicological analyses show only natural seasonal variations. The extremely low numbers of unicellular organisms, algae and their skeletons found in water samples from the riverbed probes, as well as the local hydrogeological measurements – primarily dissolved oxygen measurement – indicate that the natural filtration effect in the vicinity of the riverbed probes is adequate.

Within the regional model, smaller-scale, higher-resolution and more detailed model areas were examined to ensure that the impact assessment was conducted with sufficient quality (the surroundings of the prospective water resources of Csámpa-puszta and Gerjen-north, the environments of the operational Kalocsa-Fadd drinking water resource and the vicinity of the planned alternative warm water canal section).

The Csámpa-puszta water supply, which exploits Upper Pannonian aquifers, has not experienced a significant change in the volume of water extracted in recent years (2013-2024), the operational water level associated with maximum production causes a depression of 10 meters maximum. Numerical hydrodynamic modelling results have shown that the extraction from the water resource does not cause a change in vertical flow direction significant enough to have a major impact on near-surface aquifers so consequently, the operation of the Paks NPP does not have a negative impact on the drinking water resource.

Based on heat transport modelling, it can be stated that during low-flow periods – which are critical in terms of heat load – temperature anomalies of up to 3°C may develop in the fine-grained sandy formation, up to 0.5°C in the gravel formation and 1-1.8°C in the layers beneath the Danube. The role of bank-filtered water withdrawals is significant. These are capable of locally increasing or decreasing the temperature. However, the effect measured in the wells, ranges from 0.05 to 0.3°C, which falls within the measurement limit.

3.2.4.2. Impacts of the SSLE

Under the current operating conditions of the Paks NPP the SSLE will not cause any changes regarding the operation of the Csámpa aquifer. The conditions described in the baseline study (2024 conditions) will remain unchanged. Modelling calculations have demonstrated that the depression zone forming around the wells of the water source does not reach the surface, meaning that the aquifers storing drinking water are not threatened by surface contamination. The on-site contamination cannot reach the wells of the Csámpa-puszta water supply area because the impact of the increased production has no surface cross-section and the recharge area does not point toward the power plant site but on the contrary, water flows from the west and northwest toward the wells of the water supply area.

The current conditions existing around the current operation of the Paks NPP do not result in any changes on the Gerjen-North prospective water supply area due to the SSLE of the plant.

The wells of the Foktő-Barákai aquifer are located on the left bank. However, due to the high extraction through the individual wells – exceeding as much as 2,000 m³/day – it receives replenishment not only from the left-bank riparian zone but also from areas beyond the main water stream. For these reasons, the right-bank plume with elevated temperatures due to the operation of the Paks II NPP also contributes to the replenishment of the wells' water. All of this causes a temperature increase both in the terrace deposit and in the vicinity of the wells. In the event of a low-flow rate by the Danube at 790 m³/s, the maximum temperature increase in the riverbed sediment beneath the plume is 1-1.5°C, while in the zone near the left bank it is 0.1-0.4°C. In the vicinity of the wells, the impact of temperature increases dropped to below 0.1-0.05°C. Overall, it

can be concluded that the commissioning of the Paks II NPP has no impact either on the water production on the left bank or on the bank-filtered water resources located in the left-bank zone.

Regarding the thermal impact of the parallel operation of the Paks NPP and the Paks II NPP on groundwater, it can be concluded overall, that the effects are negligible even under highly conservative assumptions. It is also evident that the effects of individual warm-water channels and channel sections are detectable directly below the surface, limited to the area of the currently operating channel section, with a slight temperature increase of less than 0.5°C, but typically less than 0.3°C.

In the terrace deposit, this effect continues to disappear. Thus, although the accumulation of these effects can be observed, this occurs at such low temperatures – at most around 0.2°C – that the resulting combined effect can also be considered negligible. All of this also means that each warm-water channel has a distinct area of influence, meaning that the effects can be determined both individually and collectively through simple summation.

3.2.5. Impacts on wildlife and the ecosystem

With regard to wildlife and the ecosystem, the operation of the currently operating NPP units to date was examined, as well as the nature and extent of the impact that the set of all influencing factors occurred related to the operation in the recent period imposed on wildlife as an environmental element and the areas of impact where these effects were observed. In addition, based on the results and conclusions of the impact assessment covering the past period, the impacts expected to occur on wildlife and the biotic communities within the impact area during the period of the SSLE of the Paks NPP were objectively evaluated.

The impact assessment relies, on one hand, on the results of current biomonitoring studies that form the basis of the environmental impact assessment as key findings characterizing the current state and on the other hand, on data and information available from surveys conducted during the earlier operational period of the Paks NPP.

The area covered by the studies was a 10-kilometer radius around the NPP. Within this, the assessment area was divided into two parts. Firstly: more detailed biological surveys were conducted within a 3-km radius around the plant site, since for most of the factors related to the plant's operation that could potentially affect wildlife, the impact radius was 3 km or less based on previous studies and secondly: field surveys were conducted outside the 3-km radius and within the 10-km radius to assess the indicator species and habitat types of the Natura 2000 sites located there. The main objective of the data collection was to lay the grounds for preparing the Natura 2000 impact assessment documentation relevant to the Tolnai Danube Natura 2000 site located within the impact area (10 km radius) of potential wildlife protection.

The assessment of the impacts of normal operation – characteristic of the NPP's past operating period – on wildlife was conducted methodologically by comparing the current survey results from 2024-2025 with the results of the 2001-2004 and 2011-2012 surveys and, since the data from regular monitoring surveys on the Danube's biodiversity are available, the comparison could be extended to the status all the way up as of 2021. Based on the results of the comparative analysis conducted separately for each studied organism group, it was determined whether, or not any differences could be observed between the previous status and the current status as determined by the 2024-2025 surveys. In the next step, the detected differences were evaluated to determine whether they can be causally linked to the factors identified in connection with the normal operation during the past operating period of the NPP and which were preliminarily identified as factors potentially affecting wildlife based on literature data and private experience.

The comparative assessment found that, for the studied groups of organisms, in most cases the differences observed between the past and present conditions cannot be linked to the factors identified as potentially affecting wildlife in connection with the normal operation of the Paks NPP. In most cases, the observed differences can be attributed to other factors, such as the aridification typically associated with global climate change.

Construction activities with significant environmental impacts will take place during the construction of the alternative warm-water channel section and the connected peak cooling system, as well as other connected facilities (e.g., structures, pipelines, electrical equipment).

From the perspective of wildlife, the indirect impact area of the construction phase includes those areas where the effects of construction work are not direct in a physical sense (e.g., land occupation), but indirectly, through their impact on other environmental elements (e.g., air, groundwater or surface water), thereby influencing the life processes and behavior of a component of the wildlife (individuals and populations of species comprising the wildlife) and consequently affecting the development of the species' population in the given area (e.g., reproduction rate and through this, population size).

According to available ornithological survey data, the area most directly affected by the construction work for the planned alternative warm-water channel and peak-load cooling system – that is, the immediate impact zone for wildlife protection – are inhabited by the Red Kite (*Milvus milvus*), the Black Kite (*Milvus migrans*) and the White-tailed Eagle (*Haliaeetus albicilla*) occur as nesting species, which are more sensitive to acoustic and visual disturbances than other species nesting in the assessment area. Based on current knowledge, among the species occurring in the area, the White-tailed Eagle is the most sensitive to acoustic and visual disturbances caused by human activity; so information regarding this species had to be used as a basis when determining the indirect impact area, which extends to an area with a radius of approximately 0.5-1 km around the construction site.

In connection with preparations for the subsequent extension of the service life, the factors typically connected with the construction activities were examined with regard to wildlife as an environmental element. On one hand, the land occupation required for the construction of the alternative warm-water channel section and the connected pumping station and of the cooling cells of the peak cooling system and the related facilities in addition to the project areas associated with construction processes represent direct physical impacts. On the other hand, the factors causing the indirect impacts of the construction work on the facilities, such as air pollutant emissions and noise emissions resulting from construction work, as well as visual disturbance arising from the presence and movement of construction personnel and machinery.

Based on the assessment, it can be concluded that, with regard to the factors listed above – identified in connection with the preparation for the subsequent extension of the service life as potentially affecting wildlife – no significant negative impacts can be detected for any of the studied organism groups. Although the interventions will locally affect habitats in the area affected by the footprint of the planned facilities and the occupation of the project area required for the construction, the population segments of the studied organism groups associated with these habitats, the condition and size of the affected habitats and the composition of the associated communities of species, the expected impacts are tolerable for all studied organism groups. This conclusion is justified by the fact that they do not induce lasting, irreversible changes in the populations of the affected species living in the region.

In view of the expected impacts on wildlife resulting from the subsequent extension of the service life, the operational impact area must include the areas of occurrence of those factors associated with the normal operation of the NPP which, based on the impact assessment, exhibit any detectable, even minor, but assessable impact or is likely to do so based on literature data. These factors define the impact area during the period of the SSLE as well.

Furthermore, the impact area of operations includes all such areas where the planned new facilities, in this case the alternative warm-water channel section, as well as the cooling cells of the peak cooling system and other related facilities, will result in a permanent change in the characteristic values of the ecological environmental factors that actually influence the occurrence of the species comprising the local biotic community compared to the current baseline condition.

The influencing factors arising during the period of the SSLE are fundamentally the same as those, typical of the past operating period of the NPP, both when the Paks NPP operates independently and concurrently together with the Paks II NPP. The discharge of warmed cooling water into the Danube resulting from the operation of the alternative warm-water channel section and the connected facilities (heat load, changes in water quality driven by the process

wastewater) does not constitute a new environmental impact. However, with the construction of the new discharge point on the Danube, this impact will occur at the new outlet location.

During the SSLE, if the Paks NPP operates standalone, the magnitude of the impact of the factors examined and the level of environmental load are expected to be exactly the same as those, characteristic of the previous operating period. The only difference expected is that the warmed cooling water will be discharged into the main channel of the Danube either via the current warm-water channel, or via the new alternative warm-water channel section, but the volume of cooling water and the extent of the thermal load will remain the same. Consequently, the impacts on wildlife as an environmental component – and specifically on the studied organism groups – will be virtually identical to those detected during the previous operating period, both in terms of the nature and extent of the impacts. However, the effects of climate change must be taken into account, the impact assessment was conducted with this in mind.

If the warmed cooling water is returned via the alternative warm-water channel section, then the nature and intensity of the expected impacts in the worst-case scenario (assuming the peak cooling system is not operational) are expected to be identical to the current situation, but the impact area will shift 400 m downstream and the 800-1,000 m impact area extending into the Danube will begin at the mouth of the alternative channel section, where measurable adverse deviations are expected.

During the period of the SSLE, in the case of the concurrent operation of the Paks NPP and the Paks II NPP, all impact factors potentially affecting wildlife as an environmental element are identical to the impact factors already presented in connection with the standalone normal operation of the Paks NPP. However, in the case of the concurrent operation of the two NPPs, these identical factors exist for the operation of two facilities thus the impacts they cause are cumulative.

The impact on aquatic life resulting from the thermal load caused by the concurrent operation of the two NPPs will be mitigated during critical periods by the operation of the new alternative warm-water channel section and the peak cooling system planned for the Paks NPP, as well as a similar peak cooling system planned for the Paks II NPP.

In assessing the impacts of emergency scenarios on wildlife and the ecosystem, only those emergency scenarios were considered for which there is an assessable and significant probability of occurrence. These are typically incidents with a small, affected area and local impacts.

Among these emergency scenarios, the release of hazardous substances into the soil may have a direct toxic effect on higher vegetation, orthoptera, butterflies, soil-dwelling arthropods and amphibians. The area affected by the adverse direct impact is essentially the NPP site and, through seepage, at most, its immediate surroundings. In the event of such an emergency case, indirect, toxic effects via the food chain on birds, bats and certain other mammal species – primarily those occurring at the site or in its immediate vicinity – cannot be ruled out.

In the event of water pollution via the warm-water channel, contaminants may enter the receiving Danube River, so the affected organisms are primarily the communities of species that make up the Danube's aquatic ecosystem. Depending on the nature of the contaminant, the expected effects may include various toxic effects. In the event of such an incident, indirect toxic effects transmitted through the food chain cannot be ruled out, these may occur through the consumption of food organisms exposed to direct or indirect poisoning. The immediate impact area of such an incident is typically the right bank of the Danube section downstream of the warm-water channel outlet, the downstream extent of which depends on the toxicity and degradation characteristics of the toxic substance, as well as the persistence of the toxic substance itself. According to the results of the model calculations performed for the incident scenario considered in the impact assessment (the discharge of untreated wastewater into the Danube resulting from the malfunction of the NPP's wastewater treatment plant), the concentration of contaminants entering the Danube is so low due to mixing that it is largely below the detection limit.

3.2.6. Generation and management of non-radioactive waste

In connection with the operation of the NPP, the generation of inactive solid waste similar to household waste (municipal waste) and production waste (non-hazardous and hazardous) is to be calculated with. Based on operational data and environmental reports regarding the waste management system of MVM Paks Atomerőmű Zrt., it can be concluded that the current system for the management of non-radioactive waste in place at the site has been proven in practice to be according to the law, controlled and reliable and is also capable of managing the additional waste streams that will arise during the preparation and implementation period associated with the SSLE without any compliance risks. Waste management begins with source-separated collection near the point of generation, conveyed through the infrastructure of on-site temporary storage and operational collection points until the documented transfer to the licensed operator, ensuring full traceability for the waste streams. The system's operational logic is not based on on-site accumulation, but rather on ensuring that waste is recycled, or disposed of in an organized, controlled and verifiable manner following its generation.

Based on quantitative data from the 2014-2023 period, which represents the period of normal operation, the volume of production waste remains consistently high. However, the annual and inter-annual trends in waste generation can be explained primarily by major outage cycles as well as the schedules of reconstructions and technological interventions. During this period, the mean annual volume of non-hazardous production waste was approximately 1,180 tons/year and typically fluctuated within the range of about 700-2,200 tons/year, while the annual volume of hazardous production waste averaged around 390-400 tons/year.

For non-hazardous types, the recovery rate ranged between 60-90% for the major portion of the period under review and in particular year's recovery approached 90%, indicating the effectiveness of selective collection, the consistent separation of recoverable material streams and practices consistent with the waste hierarchy.

According to the forecast for the preparatory period of the SSLE, the total amount of surplus waste to generate is typically in the range of 420-560 tons/year. However, peak values are expected in 2031 and 2032, when the surplus could reach 700-760 tons/year. The composition of this additional waste during that period is predominantly non-hazardous, with the proportion expected to be around 80-90%, while the volume of hazardous waste typically ranges from 20 to 90 tons/year. The reason for the increase is typically not a continuous, uncontrolled rise in load, but rather that, in parallel with maintaining normal operations, targeted technical interventions will occur periodically that generate waste and in concentrated periods. These include reconstruction and modernization projects, partial replacements of certain equipment, renovations of auxiliary systems, condition assessments and technological cleanings, as well as related construction and refurbishment works. These activities typically generate large volumes of non-hazardous waste fractions, such as scrap metal, inert construction and demolition waste, packaging materials and other maintenance-related waste, while the volume of hazardous waste remains relatively minor overall. The proper management of additional waste streams can be handled technically and organizationally within the existing framework dedicated to collection, logistics and documentation, thus the maintenance of lawful, controlled operations can be realistically ensured.

Waste generation during the period of the SSLE is more moderate and consistent in most years, with forecasts typically ranging from 100-350 tons/year. Within this, the volume of non-hazardous fractions is typically 50-300 tons/year, while hazardous types remain in the range of a few tons to a few tens of tons/year in most years thus, their proportion generally ranging between 5% and 20%.

In terms of the nature of waste generation, among non-hazardous fractions, metal waste – particularly iron and steel waste – as well as inert construction and demolition waste, packaging waste, green waste and cable waste are prognosed to be dominant. Iron and steel scrap represent a significant proportion of the non-hazardous waste and on its own can reach more than 50% of the total non-hazardous volume, which is consistent with the technical nature of the site and the fact that during maintenance and reconstruction work, a significant volume of metallic material becomes waste, typically well-suited for recycling. Among the hazardous fractions, waste

associated with the operations and maintenance of the technologies typically dominates, specifically, used oils and oily water, hazardous aqueous liquid waste, contaminated filters and absorbents, as well as certain chemical waste streams.

Based on the assessment of environmental impacts related to waste management, the impacts are typically minor, periodic and localized, primarily associated with material handling, collection and storage activities within the site. During normal operation, typical impacts comprise noise from internal logistics, the possibility for dust generation and periodic increases in traffic volume, which, with appropriate organizational measures, do not cause lasting changes in environmental conditions.

In summary of the above assessment elements, it can be concluded that the site's current conventional (non-radioactive) waste management system has been proven in practice to be suitable for the safe and lawful management of the waste streams generated. The current waste management system not only functions properly under the current operating conditions, but will also be capable of maintaining legally compliant, controlled, traceable and environmentally safe operation and waste management will not pose an environmental burden, or risk of such a magnitude that it would limit the feasibility of the planned activity.

3.2.7. Impacts on noise and vibration levels

As a major industrial facility, the Paks NPP creates noise pollution in its surroundings and also induces vehicle traffic in its operation that needs to be considered on the access routes. To assess the current environmental noise situation related to the operation of the NPP, baseline measurements were conducted on-site. The noise exposure from baseline road traffic was determined based on noise calculations using vehicle traffic data.

The operational noise exposure and background noise levels of the Paks NPP were assessed within the assumed direct impact area, in the nearest protected area, at the nearest protected facilities, measured within a radius of approximately 3 km from the center of the site. Based on the on-site investigations, the operational noise exposure from the Paks NPP is low in the surrounding residential areas therefore, it is not perceptible, or measurable independently of background noise.

The additional traffic noise exposure was considered along the main routes affected by traffic related to the NPP – Main Road No. 6 and the M6 highway – within a maximum distance of 25 km from the site of the core activity (the Paks NPP) in the settlements of Paks, Dunaszentgyörgy, Dunaföldvár, Tengelic and Fácánkert.

With regard to baseline road traffic noise levels (background noise), noise levels at the reference points to be protected along the M6 motorway remain below the limit values at all measurement points. At the reference points to be protected along Main Road No. 6, with the exception of Dunaföldvár and Paks Csámpapuszta 22, the limit values are exceeded by a few decibels (dB) at the test points during daytime and/or nighttime hours.

From a noise assessment perspective, the environmental factor to be examined in relation to normal operation is the noise emissions from the NPP's noise-generating equipment - as noise sources. The effects resulting from direct noise emissions are primarily observed within the plant site. Eight steam turbines operate in the turbine halls of the main buildings of the Paks NPP. The equipment of the transformer station located in the eastern part of the building connect to these. The cooling and ventilation plant can be found next to the central part of the main building. To the plant's operation belongs the two water intake plants at the end of the cold-water channel with submersible pumps. The 12-bar firewater pump house and two additional pump houses are located on the eastern boundary of the plant site. The outdoor transformer station and the network control room are located on the southeastern edge of the site. The high-pressure compressor is located in the building on the southern boundary of the plant site. The cooling water taken from the Danube through the cold-water channel and used is discharged into the warm-water channel via the level-regulator weir. The water from the warm-water channel is returned to the Danube. The forces resulting from the flow velocity are absorbed by the energy dissipation structure before the water is returned to the river. Activities carried out in the maintenance workshops on-site are

necessary for the continuous operation of the NPP. The hydrogen building, which currently functions as a low-pressure compressor house, is located in the southeastern part of the power plant site.

The actual noise exposure from the Paks NPP at distant exposure points requiring noise protection (where the plant's noise exposure is already so low that it cannot be measured locally) was determined based on a noise propagation model using measurement points near the operational noise sources of the plant. Based on the noise modeling, it can be concluded that the current environmental noise exposure from the Paks NPP remains below the prescribed noise exposure limit. The current operational, noise protection related impact area of the NPP touches the administrative boundary of Paks and Dunaszentbenedek. However, it does not affect residential areas or protected zones located in the vicinity of the plant. From the perspective of environmental impact assessment, the operational noise exposure of the NPP can be classified as long-term and neutral with regard to surrounding buildings and areas that require protection, while within the operational area it is considered as burdensome.

According to the results of previous studies, vibration levels – neither the baseline nor with respect to the Paks NPP – are not expected to reach critical levels.

The indirect impact of the NPP's operation is characterized by noise emissions from traffic-related sources as influencing factors. Based on vehicle traffic data related to the operation of the Paks NPP, higher noise levels occur on Main Road No. 6 between Dunaszentgyörgy and Paks-Northern access route, yet no increase in noise levels related to plant-related traffic can be detected on the M6 motorway. An indirect impact area develops along affected road sections, specifically near the residential buildings adjacent to the Paks-Csámpa road. From the perspective of environmental impact assessment, the traffic noise impact of the NPP on buildings and areas that require protection is classified as long-term and falls into the neutral-tolerable categories.

Among the activities planned as part of the preparations for the SSLE, noise emission assessments need to be performed owing to the construction of the alternative warm-water channel section and the peak cooling system. The main factors during the construction period are the noise emissions from construction machinery causing noise pollution. The phase of the construction expected to cause the highest noise levels is that of the earthworks carried out by heavy machinery. For the assessment of the construction impacts, daytime work was considered.

During the construction of the alternative warm-water channel and peak cooling system, the noise exposure limits for construction activities are expected to be met. The noise impact area resulting from the construction of the peak cooling system affects the vicinity of the construction works within a radius of 400-600 m, extending to zones not requiring noise protection and the economic area of the Paks NPP that does not comprise protected facilities. The impacts resulting from noise emissions can be considered neutral during the construction period.

With regard to the duration of the SSLE, no significant change is expected compared to the current noise exposure, with the exception of the periodic operation of the forced-draft cooling cell peak cooling system during critical periods. In the absence of peak cooling system operation, the current exposure level can be expected to continue. Following the commissioning of the peak cooling system, the condition that comes with the highest noise level will be when the warmed cooling water is returned to the Danube via the new, alternative warm-water channel, passing through the cooling cells of the operating peak cooling system.

During the extended service life, the current noise sources of the Paks NPP will be supplemented with additional noise sources, including the new level-maintainer weir, the new energy dissipation structure, the fans and air intake openings of the cooling cells, the transformer and the pumps in the pump station. Noise reduction measures will be designed for the peak cooling system of Paks NPP to ensure that noise exposure limits for the affected areas are met even during the concurrent operation with the Paks II NPP.

When the Paks NPP is operated using the peak cooling system, the standalone noise exposure by the plant is expected to be classified from the perspective of environmental impact assessment

regarding surrounding buildings and areas that require protection as long-term, with burdensome impacts in Uszód and within the plant site, yet neutral in other protected zones.

When the Paks NPP operates with the peak cooling system, the Paks II NPP will also be in operation, the combined noise exposure and impact area were examined and presented accordingly. In the assessment of noise exposure during the joint operation, the noise sources of the Paks NPP were supplemented by the peak cooling system and the operational noise sources of the Paks II NPP were taken into account.

The noise exposure associated with the joint operation of the Paks NPP and the Paks II NPP is expected to approach the zone limit values in the nearest residential areas, both with and without considering the operation of the peak cooling system of the Paks NPP. However, with appropriate noise reduction measures, it will not exceed these limits. During the construction of the peak cooling system of the Paks NPP, noise reduction measures must be implemented and designed in such a way that noise levels, which are already expected to be close to the limit values, do not increase and the affected area does not expand significantly.

The joint operational noise impact area of the Paks NPP and Paks II NPP, both with and without considering the operation of the peak cooling system of the Paks NPP, falls within a circle with a radius of approximately 2.3 km, centered on a point shifted east-northeast from the center of the Paks NPP site, extending into the administrative areas of Paks, Dunaszentbenedek and Uszód, also affecting the residential areas of Paks-Csámpa, Dunaszentbenedek and Uszód.

Based on the archived baseline vibration measurements conducted as part of the environmental impact assessment for the Paks II NPP, the environmental vibration exposure from the Paks NPP is below the limit value. The vibration load resulting from traffic related to the operation of the NPP is not expected to be significant. In the case of the concurrent operation of the Paks NPP and the Paks II NPP, the effect of vibration load is expected to be a long-term on the population to be protected, from the perspective of environmental impact assessment. However, this can be classified as neutral. With regard to vibration sources, no changes are expected for the duration of the SSLE. The current load can be taken into account during the continued operating period as well.

In forecasting future traffic noise levels associated with the operation of the NPP, assuming the most unfavorable scenario (the largest impact area), the impact area developing due to the increase in noise load exceeding 3 dB by a few tenths of a decibel, representing the current levels can be assumed to persist even at the beginning of the initial years of the subsequent service life. When examining the longer-term forecast (15 years or the entire service life of the plant until 2057) it is more likely that, in the distant future, no impact area will develop along the affected roads as an indirect effect of the NPP, since the baseline traffic on these roads is increasing each year, whereas the impact area resulting from traffic noise from the Paks NPP will relatively decrease, or become undetectable. The Paks-Kalocsa Bridge over the Danube (the Pal Tomori Bridge) does not significantly affect the traffic noise load of the NPP. During the period of the continued operation, the indirect impacts can be considered neutral.

The road traffic noise resulting from vehicle traffic related to the operation of the Paks II NPP – based on the environmental impact assessment prepared for the Paks II NPP – will cause a slight increase in noise exposure along Main Road No. 6 and will slightly expand the indirect impact area of the Paks NPP. The combined potential indirect impact area of the Paks NPP and the Paks II NPP will develop near the residential buildings along the roads of Paks-Csámpa and Dunaszentgyörgy during the initial years of the SSLE. The combined traffic noise exposure from the Paks NPP and the Paks II NPP is classified as long-term in terms of environmental impact assessment and with regard to buildings and areas that require protection, is expected to fall into the neutral-tolerable categories depending on the location. In the distant future, impact area will not develop along the affected roads as an indirect effect of the combined traffic noise exposure from the Paks NPP and the Paks II NPP.

In terms of noise emissions, the simultaneous loss of external power supply and internal AC power supply (in all four units) was taken as the basis for an emergency scenario. The probability of such a significant incident to occur is very low.

The factors influencing noise levels during an emergency are the noise emissions from noise sources that remain operational in the event of a malfunction. For the emergency scenario, partial operation of the main buildings I and II was taken into account. The point-like noise sources of the roofing were supplemented with the noise emissions from the safety valve blowdown to the atmosphere compared to normal operation. In addition, the noise emissions from the emergency diesel generators must also be taken into account during the emergency operating condition.

In terms of noise exposure, noise emissions during an emergency remain below the noise exposure limit at the nearest buildings and areas that require protection, provided the emergency occurs during the day. In case the emergency occurs at night, the noise exposure exceeds the limits at most monitoring points. There is a significant difference between daytime and nighttime noise levels because the noise sources producing the highest noise levels operate intermittently and this noise is averaged over the assessment period specified by law, which differs between night and day.

In the event of an emergency, the noise impact area varies in size depending on the direction, in accordance with the applicable zoning categories, the farthest point is likely to be approximately 5 km from the center of the Paks NPP. From the perspective of environmental impact assessment, the operational noise exposure from a NPP emergency event represents a short-term and burdensome impact on the surrounding building facades and areas that require protection. The emergency impact area affects the settlements of Paks, Dunaszentgyörgy, Uszód, Foktő, Dunaszentbenedek and Géderlak.

3.2.8. Landscape, land use and settlement environment

In the vicinity of the NPP, large-scale arable farming is the dominant land use. Deciduous forest plantations, territories of settlements and flowing water bodies (primarily due to the Danube's water surface) cover significant areas. In recent decades, a decrease in meadow areas has been observed. Based on the region's landscape potential, it can be concluded that, due to its natural features, it possesses high ecological potential – deriving from the land use, agricultural and forestry potential – and due to the industrial facilities – the town of Paks also has high industrial potential.

From a landscape perspective, the most significant impact during the preparatory phase of the SSLE is land occupation. In the current case, this causes only minimal change, as an existing facility fundamentally does not need to occupy new areas. The reconstruction and renovation work required as part of the preparatory activities will be carried out within the site. An exception to this is the land use required for the alternative warm-water channel section and the connected peak cooling system planned for implementation during the preparatory phase. The location for this has been designated south of the current warm-water channel, partly within the industrial area, partly occupying flooding areas and parts of the fishpond, remaining largely within the Paks NPP site. More than half of the required land area is currently part of the site and is an industrial area. Out of the total 21.25 ha of land occupied, 0.65 ha is currently designated as forest (outside the industrial area) and 3.47 ha as fish ponds. Nearly 1.9 ha is part of a Natura 2000 site. Given that access to the section of the warm-water channel located in the floodplain must be ensured in the long term, during the operational period, it is necessary to account for the use of 0.78 ha of planned forest and 2.1 ha of Natura 2000 area compared to the current status. The planned land occupation affects 0.78 ha of secondary forest. Therefore, in accordance with legal regulations, afforestation is not mandatory and the land use can be concluded paying a forest compensation levy.

The occupation of the required additional land will alter the land use in a sense that in the areas occupied, industrial land use will replace the previous, primarily forestry-related land use, the natural or near-natural area will come under human influence and take on a man-made appearance. This relatively minor change will not have a significant impact on the landscape structure or character. Thus, the consequences of the change in the land-use are classified as tolerable.

The use of the floodplain forest along the Danube can be cited as a change in landscape value. The development will cause a change in the landscape also, as the “absence of a forest” will be more prominently visible in the view than the new canal or the sight of the cooling cells, which will be partially obscured by the embankment. No significant change in the view is expected due to the clearing of the forest patch, as similar forest landscapes can be found in the background, on the islands and on the opposite bank of the Danube. The impact is tolerable.

The installation and construction of the planned new elements will affect the most among the surrounding land uses, the recreational use of the fish ponds to the south and southwest. However, this impact will be limited to the relatively short period of the canal’s construction and the placement of equipment and will be tolerable.

No increase in land occupation is expected during the extended service life. From this perspective, the impact is neutral. Since this is an existing, operational power plant, the landscape structure is not expected to change during the continued operation; the current landscape structure developed during the construction and/or operation of the NPP and its connected facilities, meaning that the impact on the use of the surrounding areas has already taken effect. Among the surrounding land uses, the peak cooling system to be installed alongside the new alternative warm-water channel section may have an adverse impact on the recreational activities at the adjacent fishing lake (noise, visual impact). However, operation of the peak cooling system will only be necessary during periodic, critical periods when low Danube and air temperatures coincide, meaning the equipment is expected to operate only for short periods each year. The impact is considered as tolerable.

No land-use conflicts of a new kind or of a different magnitude than those experienced to date, are expected to occur during the continued service life. In the longer term, only the use of Danube water and the discharge of warm water could cause conflict if, due to climate change, low-water flow rates decrease or the water temperature rises to the point where it may become necessary to limit the output of the NPP. However, this is expected to occur only for short periods in the future also and any adverse consequences can be managed by the planned alternative warm-water channel and the connected peak cooling system and operational measures. The expected impact is therefore likely to be neutral.

The planned continued service life is not expected to affect the preservation of the values to be protected with the exception of the use of forest land affecting the Danube floodplain due to the construction of the alternative warm-water channel section and the new discharge point into the Danube. However, this will occur only in a very small area of the Danube floodplain and moreover, similar floodplain forests will remain adjacent to the areas occupied, so the loss of value is negligible from a landscape conservation perspective. The impact on landscape values is assessed as neutral.

Changes in the landscape and its character are generally associated with the construction of a facility. In the case of an operational facility no further changes to the landscape are expected to occur. The landscape character represented by the facility during the continued service life period will be identical to the current state, as the nature, mass and thus the appearance of the buildings and structures will not change. The visibility of the planned cooling cells is limited. The impact thus can be considered as neutral from this perspective also. The visibility of the power plant, both currently and during the extended service life is limited to sub-areas within an approximately 8 km radius of the plant that are not obscured (primarily by forests and the structures of settlements). From a landscape perspective, this can be considered as the impact area.

Regarding the impacts of the concurrent operation of the Paks NPP and the Paks II NPP, land occupation and landscape use will not change, as the Paks II NPP site was previously an industrial area reserved for the extension of the power plant. However, the area, which has been largely undeveloped to date, will become a significantly built-up, paved and intensively utilized area, where the functionality will change substantially with the addition of electricity generation activities.

In terms of landscape character within the industrial environment, the operation of the Paks II NPP will not cause any significant changes, as the height and mass proportions of the two planned

new units are similar to the character of the operating Paks NPP. The combined appearance of the two NPPs is expected to be tolerable within the landscape.

From the perspective of the environment around settlements, the effects of normal operation are identical to the characteristics of the baseline condition, as the existence and operation of the NPP have shaped the current land use structure and the characteristics of the settlement environment.

Based on the content of the land-use plans reviewed at the national, county and municipal levels, it can be stated that no significant changes are expected regarding land-use units and spatial structure elements as a result of the subsequent extension of the service life. The land development objectives previously defined due to the existence of the NPP are fundamentally consistent with the long-term or planned elements outlined in the land-use and municipal development plans.

The construction of the alternative warm-water channel and the installation of the peak cooling system will influence the NPP's industrial economic zone, the water management area (fishing lakes, flood protection embankments) and a narrow strip of forest land designated for protective purposes. For this reason, a minimal modification of the land-use plan will be necessary.

Among the general environmental characteristics of the town of Paks, the town's natural-geographical and spatial-structural position is not expected to change as a result of the subsequent extension of the service life. Changes are not expected in the characteristics of technical and other infrastructural or institutional services either; their condition can be maintained at a level corresponding to the current, thanks to the significant economic importance of the facility.

In the local environment, the condition of protected assets and those considered worth preserving (built environment, green spaces and historic monuments, or archaeological remains as part of the cultural heritage) located both in the immediate and broader vicinity of the power plant is not expected to change in connection with the plant's continued operation. The possibilities for their preservation and maintenance will remain unchanged thus, the continued operation will not affect the vulnerability of these values. The service life extension, therefore, has a neutral impact from the perspective of protected values. From the perspective of the local environment, the impact area can still be considered primarily identical to the administrative territory of Paks.

Due to the existence of the Paks NPP and the construction of the new NPP, the previously defined regional development objectives are fundamentally consistent with the long-term or planned elements outlined in the land use and municipal development plans. Among the general urban environmental characteristics of the town of Paks, the city's natural geographical position will not change during the concurrent operation either. The spatial structural position may improve in parallel with the concurrent operation of the two NPPs and the economic strengthening of the town.

3.2.9. Social and economic impacts

The demographic trends characteristic of the plant site and its broader surroundings align with national trends. Population decline, negative migration balance and aging have fundamentally determined population changes in the examined settlements for decades. At the same time, Paks is in a somewhat more favorable position, for example, owing to a younger age structure and higher educational attainment at the county level or due to a higher employment rate per household and higher per capita income at the national level.

The current demographic trends have a significant impact on the results of demographic projections, which suggest that existing population trends are likely to continue through 2062, but the rate of population decline will be more intense than the national average. Population change is expected to be accompanied by anticipated characteristic differences within the Paks region in the long term as well. The town of Paks is expected to have a more favorable ability to attract workforce in the future, which, as the only factor in the studied area to positively impact its demographic outlook compared to the surroundings.

The demographic situation may influence economic opportunities not only in the present but also in the future. Based on GDP per capita, the economic strength of Paks and its broader surroundings is approximately three-quarters of the national average. In Tolna County, Paks is considered as one of the main economic power hubs thanks to the NPP, demonstrating economic indicators in many cases even better than those of the county seat, Szekszárd. The dynamics of the economy in the region are restrained, as sectoral specialization does not establish a stable foundation for long-term growth. Based on various conditional scenarios, significant reduction in the cross-sectional differences of the regional development is not expected according to long-term economic forecasts. Paks and its immediate surroundings demonstrate a better than the national average economic performance, but its local overflow effects are limited to a confined area.

The examined social and economic consequences suggest that no significant transformation is expected in the long term within the 30-kilometer radius surrounding the Paks NPP. The subsequent extension of the NPP's service life and the associated environmental impacts will not result in significant changes to existing processes, trends, or phenomena. The occupation and usability of areas affected by the NPP's environmental impacts are not expected to be influenced by the implementation of the SSLE, since this involves extending the service life of a facility that is already in operation.

Socio-economic impacts resulting from changes in land use (e.g., the loss of jobs and farmers' sources of income due to the use of previously agricultural land for industrial purposes, or the impossibility of continuing agricultural operations due to the environmental impacts of the planned activity, changes in the structure of employment and income patterns) are generally not expected. An exception to this is the change in land use in the short section of the Danube riverbank area affected by the alternative warm-water channel outside the power plant site, where part of the forested area will be used for industrial purposes. The use of the forested area was primarily a relevant issue to be examined from the perspective of wildlife and ecosystems. Significant social, or economic impacts are not likely in this case either. Furthermore, the planned modification for the subsequent extension of the NPP's service life is considered to be in the priority public interest.

The current standard of living for the population in the region affected by the NPP's environmental impacts will not change significantly. The social and economic trends currently observed are not expected to result in a turning point, or major change before 2060.

Overall, the main finding of the subject-area studies conducted is that the SSLE until 2052-2057 will maintain the current situation in terms of social and economic consequences in the immediate and broader vicinity of the site (in view of e.g., employment, quality of life, economy, etc.) and significant changes could occur precisely if the Paks NPP were to shut down in 2032-2037, as the current impacts would then cease to exist.

3.3. Characterization of environmental radioactivity and expected changes due to the SSLE

3.3.1. Emissions of radioactive materials, characterization of environmental radioactivity

In the course of the operation of the Paks NPP, radioactive materials are released into either the atmosphere or the surface water (the Danube). A key difference between airborne and liquid emissions is that while airborne emissions and their monitoring are continuous, radioactive wastewater from various sources is collected in storage tanks at the plant and then discharged in batches following preliminary measurements. In the case of liquid discharges, this allows for further operational intervention (retention, concentration, dilution, etc.).

The quantity of radionuclides that may be discharged is regulated by strict regulatory limits, where the compliance is repeatedly verified by both the operator itself and the authorities. The discharge limitation system prescribed by Decree 15/2001. (VI. 6.) KöM on radioactive emissions into the air and water and their control applies to both liquid and airborne emissions, with emission limits per isotope derived from the dose limit set for the NPP (90 µSv/year).

Overall, it can be stated that throughout its entire operating period, the NPP complied with the limits on radioactive emissions in all respects with a significant margin. The power plant utilized 0.33% of the emission limit in 2024, of which liquid emissions accounted for 0.24% and airborne emissions for 0.08%. The utilization rate of the emission limit criterion in previous years was of a similar magnitude.

Based on the evaluation of the 2024 results of nuclear environmental monitoring, it can be concluded that the operation of the NPP had no directly measurable impact on the environmental radiation conditions in 2024 either. The measurement results from the dose rate probes at type “A” and “G” stations, as well as from the thermoluminescence detectors installed at all of the stations, showed dose rates and doses characteristic of natural gamma radiation in the environment.

The estimated value of the annual average activity increase in the Danube water caused by radioactive materials discharged into the Danube – after complete dilution – was less than 1.0 Bq/dm³ for tritium and less than 0.1 mBq/dm³ for all other radionuclides in aggregate.

With regard to the direct appearance of released radioactive isotopes in the environment, observations indicate that – even using highly sensitive analytical methods – no isotopes of artificial origin were detected in surface air samples taken at type “A” monitoring stations located 1-2 km from the NPP. The environmental activity concentration of radiocarbon can be estimated at around 40 mBq/m³ and tritium in the range of 10-20 mBq/m³ (mostly 10-400 mBq/m³ in case of A3 and A4 stations) and radioactive noble gases in the same area around 100 mBq/m³. No artificial isotopes of NPP origin were detected in fallout samples throughout the year.

No radionuclides originating from the NPP were found in any of the soil and grass samples taken in the vicinity of the stations, nor in any of the Danube sediment samples. In water and sediment samples from fish ponds, as well as in milk and fish samples, no radioactive isotopes from emissions were identified above the detection limit. Summarizing the 2024 measurement results of nuclear environmental monitoring, it can be concluded that – similar to previous years – the impact of the NPP on the environment was negligible from a radiation protection perspective.

As part of the environmental impact assessment, the planned conversion of spent fuel management (including the interim storage of additional spent fuel generated during the SSLE as part of the transition to the new Holtec HI-STORM UMAX technology) included a review of the operations related to servicing the casks within the plant systems and the associated emissions which was completed. The contribution of the new technology, arising from the preparation for the interim storage of spent fuel elements, will not be significant in terms of the current radioactive emissions of the NPP.

Radioactive emissions from the Paks NPP are not expected to change significantly during the period of the SSLE, as no changes are planned regarding the plant’s technology, or operational features that would significantly influence the characteristics of radioactive emissions.

Accordingly, it can be stated that the current levels of radioactive emissions are expected to remain for the period of the extended service life as well. This means that, compared to the current situation, the characteristics, quantity and mode of airborne and liquid radioactive emissions will not change.

Based on experience to date, it can be concluded that during the SSLE, the magnitude of normal operational airborne and liquid radioactive emissions will remain within a range similar to that observed to date thus, the continued operation of the Paks NPP will not pose a greater radiological risk to the environment than what the case has been so far.

According to the construction licensing documents for the Paks II NPP, the plant was designed so that the level of radioactive exposure to the environment and the population during continuous normal operation of the units and during anticipated operational events does not exceed the public dose limits or the environmental radioactivity limits. To verify this, dose calculations were performed regarding the impact of the Paks II NPP during operation in the vicinity of the site. The results obtained are entirely consistent with the calculation results for normal operating emissions from the units of the Paks NPP.

During the assessment of the expected environmental impacts of the Paks II NPP during normal operation, calculations demonstrated that during normal operation of the two units of the Paks II NPP, the doses expected to affect the population from airborne and liquid emissions are significantly lower than the 90 $\mu\text{Sv}/\text{year}$ dose constraint established for the facility on its own, in fact, the dose resulting from actual emissions will be much lower than this value. During the concurrent normal operation of the Paks NPP and the Paks II NPP currently under construction, the environmental radiological exposure is expected to be negligible.

3.3.2. Assessment of radiation exposure of the public

3.3.2.1. Public doses resulting from the current operation of the NPP

Public doses resulting from the normal operation of the NPP arise from the release of radioactive materials (mostly internal radiation exposure) as well as from direct (scattered) radiation associated with operations (external radiation exposure). The total public radiation exposure resulting from NPP emissions is the sum of airborne and liquid emissions. Studies, based on both previous analysis results and the results of ongoing measurements, have concluded that the doses resulting from direct scattered radiation, as well as from airborne and liquid emissions, are very low.

The magnitude of the radiation exposure of the public resulting from the operation of the Paks NPP can be determined by calculation, using emission data and dispersion models, taking into account the various radiation pathways, rather than relying on direct measurement data. The radiation exposure determined by calculation is the sum of the doses for 1-5-year-old children resulting from airborne emissions in Csámpa and liquid emissions calculated for the population of Gerjen, as applied to the assumed “critical population group,” i.e., a representative individual with the characteristics of that group.

The maximum public dose derived from airborne and liquid emissions over the 10-year period examined (2013-2022), determined using highly conservative assumptions, was 115 nSv, which represented only 0.13% utilization of the maximum dose constraint. The maximum dose for children was even lower, at 110 nSv. These doses are approximately equivalent to the external effective dose caused by one hour of naturally occurring radioactivity and therefore do not pose a detectable health risk.

Based on the above data, the conclusion is that the radiation exposure of the population during the normal operation of the Paks NPP to date has had no detectable adverse health effects. The environmental impacts caused by the normal operational radioactive emissions of the NPP can be classified as neutral.

In order to characterise possible environmental radiological impacts during operation of the Paks NPP other than normal, events that have occurred during operation to date involving the release of radioactive material exceeding the usual normal operational emission levels may be taken into account. During the plant's operation to date, only a few incidents involving emissions from operational incidents have taken place, as a result of which the presence of radioactive materials in the environment was possible to detect.

In the case of radioactive releases from operational incidents at the Paks NPP, the detection of activity in the environment demonstrated the very high sensitivity of nuclear measurement technology, which confirmed that the releases had no environmental, or health consequences. This is supported by the fact that following the emergency-related releases – after a possible short-term increase in levels – the activity concentrations measured in water and food samples were in all cases orders of magnitude below the permissible activity concentrations and the dose rate of environmental radiation remained at the level of normal, natural background radiation. The maximum ground surface contamination by the predominant isotopes deposited from the air mass containing radioactive isotopes was equally very low and the dose rate calculated from this did not reach 1 nSv/h, approximately 1% of the natural background radiation and falls well within the range of fluctuations of the natural radiation level. The committed effective dose calculated from the intake of radionuclides via inhalation or ingestion was in the nSv range, which is extremely

low, corresponding to the radiation exposure from natural background radiation over approximately 1 minute.

3.3.2.2. *Expected changes due to the Paks NPP SSLE*

To assess the expected radiation exposure of the population living within a 30-km radius of the site during the subsequent extension of the NPP's service life, the radiological impacts that have occurred during the plant's operation to date, as well as the results of previously conducted analyses, were taken into account.

To determine the radiation exposure of the population and the radiological impact area, new analyses were also conducted as part of the environmental impact assessment for the SSLE, taking into account the most recent available data. An assessment was also conducted to determine what changes in characteristics affecting public radiation exposure – which may vary during the continued operation (e.g., meteorological and hydrological data, or the lifestyle and consumption habits of the local population) – could result in changes from the perspective of environmental impact. The assessment of environmental radiological impacts associated with the continued operation of the NPP was based on normal operational airborne and liquid emissions, as well as potential airborne emissions from design basis accidents.

To determine the radiation conditions in the environment and the doses to the public, the applicable analytical tools, the emission source categories and the circumstances of emissions to be considered were specified for each operating condition under examination, in addition to the input data to be used regarding the meteorological and hydrological conditions and the population's lifestyle and consumption habits. The radiation pathways to be considered were also determined, along with receptor points located at various distances and directions, for which specific dose values form the basis for conclusions regarding the radiological impact area.

For normal operating conditions, the public doses for 1-year-old children and adults were determined based on actual airborne emission data from 2022 (the year with the most unfavorable data for the analyses) examined in 16 sectors at various distances. In Csámpa, located approximately 1 km from the NPP in a southwestern-western direction, the calculated value of the committed effective dose for a representative individual was 3.64 nSv for adults and 1.63 nSv for children.

Based on the results, it was evident that in all cases, after the landing of the radioactive cloud on the ground (which, for the purposes of this calculation, occurs within 500 m of the emission point), the doses decreased as the distance from the power plant increased.

Regarding the dose consequences of normal operational airborne emissions for the population, it can be concluded that they fall into the neutral category everywhere in the vicinity of the NPP, remaining significantly below the 90 μ Sv/year dose constraint and the upper limit of the neutral effect category. The maximum calculated committed effective dose occurred at a distance of 500 m in the southwest direction, amounting to less than 0.02% of the 12.2 nSv dose constraint value specified for adults.

Based on the analyses, therefore, the radiological impact area of airborne emissions during normal operation remains within boundary of the safety zone (500 m) and the radiation exposure to the public can be estimated to be significantly below the 90 μ Sv/year dose constraint and the upper limit of the neutral effect category.

The analysis conducted to determine the consequences of liquid discharges was based on the NPP's actual liquid discharge data from 2021 at normal operation (as the year with the most unfavorable data for the analyses), assuming the discharge to be continuous and of point-source type along the shore.

In Gerjen, located 10 km from the NPP, the calculated committed effective dose for representative adults and 1-year-old child was dominated by the internal radiation exposure from fish consumption. Due to different consumed quantity levels, the internal and total doses for adults were higher than those for children.

Regarding the dose consequences of normal operational liquid discharges for the public, it can be stated that they fall into the neutral category everywhere in the vicinity of the NPP, with values several orders of magnitude below the dose constraint (90 $\mu\text{Sv}/\text{year}$). The value for the maximum calculated committed effective dose, 157 nSv for adults at a distance of 500 m, is less than 0.2% of the dose constraint value. Based on the current analyses, the effective committed dose for adults in Gerjen is 35.3 nSv and 31.8 nSv for 1-year-old children.

The calculation of public doses deriving from the operation of the NPP was performed not only for normal operating conditions, but also for design basis accidents. The study covered numerous initial events included in the design basis of the NPP. The values of public doses resulting from airborne emissions at receptor points within a 30 km radius were the highest in the accident scenario “break of the pressurizer injection line with a nominal diameter of 90 mm at a thermal power of 1485 MW, assuming a total station blackout” and thus, these results were taken into account.

In Csámpa, approximately 1 km from the NPP, the calculated committed effective dose for a representative adult was 425 μSv , while for a 1-year-old child it was 349 μSv . The results made it evident that, after the radioactive cloud landed on the ground, doses decreased with the increasing distance from the power plant. Based on the analyses, it can be concluded that the population dose consequences examined for design basis accidents do not exceed the upper limit of tolerable effects, i.e., the 1 mSv value. Up to approximately 5-6 km from the release point, tolerable effects (≤ 1 mSv), while beyond that, neutral effects (≤ 90 μSv) prevail as a result of the airborne releases associated with design-basis accidents.

For the examined design basis accident case, the radiological impact area corresponding to a dose exceeding 90 μSv from airborne emissions was determined for 1-year-old children and adults. Based on the new analyses performed, the impact is already neutral at distances greater than 6.0 km.

In the event of design -basis accidents, direct liquid discharge into the Danube does not take place therefore, the water dispersion analyses were performed on the assumption that, during design basis accidents, 19.1% of the total activity released into the air (except for noble gases) is washed into the Danube. The fraction of washout was determined based on the proportion of the emitted contamination being washed out over an area of an assumed 700×700 meters size during the period it takes for the contamination to pass over the area at a given wind speed.

Based on the calculations, the highest doses for water exposure pathways resulted from the accident release scenario “break of the main loop 4 pipeline with a nominal diameter of 492 mm on the hot leg at a thermal output of 1485 MW, with 2 confinement spray systems in operation.”

In Gerjen, located 10 km from the NPP, based on the results of 28.8 μSv for adults and 29.2 μSv for 1-year-old children respectively, it can be concluded that even in this scenario examined with highly conservative assumptions, the doses remain below the 90 $\mu\text{Sv}/\text{year}$ threshold value, meaning that the upper limit for neutral effects is not reached.

Due to the washout of airborne emissions, the calculated results for the aquatic exposure pathways cannot be added to the dose values determined for the atmospheric exposure pathways based on airborne emissions, since the simultaneous occurrence of the two scenarios is not possible.

If the released radioactive material is washed out of the cloud into the Danube to such a large extent, less material remains in the atmosphere. Thus, the doses of the radiation pathways determined by atmospheric dispersion would also be lower. Since the doses determined for the radiation pathways related to atmospheric dispersion significantly exceed the values presented here at most receptor points, an atmospheric release scenario was taken into account when determining the radiological impact area.

The combined radiological impact of the normal operation of the Paks NPP, the SFISF and the Paks II NPP was also examined in the environmental impact assessment prepared for the environmental licensing of the new Paks units. In the environmental impact assessment report for the Paks II NPP, the combined maximum dose from the three facilities did not reach in Csámpa the annual value of 1 μSv for either the adult population or the 1-2-year-old age group (0.154 and

0.120 μSv respectively), while the total dose at greater distances (up to 30 km) drops under 0.003 μSv (3 nSv). Further analyses conducted to determine public radiation exposure for the independent, normal operation of the Paks NPP resulted in the same order of magnitude as the <0.1 μSv value indicated in the Paks II NPP EIAR, but with slightly lower values.

The reason for these differences, irrelevant to the results, arising from the continuous development of the methodologies and tools used in the analyses, the changes in the input data considered in the calculations and the varying degrees of conservatism in the assumptions and considerations. It can be stated, however, that based on the analyses conducted within the framework of this assessment, the combined dose from the normal operation of the three facilities (Paks NPP, SFISF and Paks II NPP) remains significantly below the 90 $\mu\text{Sv}/\text{year}$ dose constraint and consequently, the upper limit of the neutral effect.

3.3.3. Impacts on the health of the population

Humans are exposed to ionizing radiation throughout their lives, partly from natural and partly from artificial sources. All living organisms on the Earth's surface are continuously exposed to ionizing radiation. The effective dose of this radiation averages 2.4 mSv/year globally and 3.0 mSv/year in Hungary. (The average dose of ionizing radiation from artificial sources on Earth is 0.4 mSv/year.) At many locations on Earth, natural background radiation is an order of magnitude higher than in Hungary, which in fact is not reflected in the incidence of radiation-related diseases; that is, variations in exposure within the range of an effective dose of 2-3 mSv/year do not result in a detectable increase in risk.

In line with previous studies of the same nature – most recently conducted in connection with the environmental licensing of the Paks II NPP – as part of the assessment of the environmental impacts of the Paks NPP SSLE, an investigation was repeatedly performed to determine the incidence of diseases potentially related to ionizing radiation among the population living within a 30-km radius of the NPP. The analyses were intended to answer the question of whether, or not – based on the actual pattern of diseases – there is any suspicion that increased risks of certain diseases could be linked to the operation of the Paks NPP.

The assessment was conducted in two phases. In Phase 1, relevant data available in Hungary's health statistics systems were processed. In Phase 2, a survey based on primary data collection was conducted, which permitted that the risk assessment be adjusted to other (non-ionizing radiation) risk factors affecting the individuals.

The assessment area – in consistence with the scope of other studies on environmental impacts – was defined with a circle of 30-km radius. Within this area, measurements and model calculations based on the measurement results confirmed that no ionizing radiation capable of causing significant biological effects was released from the NPP into the environment.

Based on the results of the studies, it was concluded overall that the operation of the NPP and its emissions – in line with the findings of previous analyses – do not result in an increased risk of diseases among people living in the vicinity of the plant.

Regarding the expected effects of the SSLE, the radiological impact is neutral under normal operating conditions with respect to atmospheric and aquatic emissions, because the combined maximum total doses from the three Paks facilities (Paks NPP, SFISF, Paks II NPP) remain two orders of magnitude below the upper limit of the neutral value under normal operating atmospheric emission conditions. For this reason, following the SSLE of the Paks NPP and the commissioning of the Paks II NPP, the same health effects are expected as during the Paks NPP's operation to date. In other words, the operation of the Paks NPP and the SFISF to date has had a neutral effect on the health of the local population and this will not change even when the Paks II NPP commences its operation.

3.3.4. Radiation exposure of the wildlife

As part of the environmental impact assessment for the SSLE, a review was conducted of the findings from the most recent comprehensive assessment on radiation exposure of the wildlife, described in the environmental impact assessment for the construction and operation of the Paks II NPP, in addition to the processing and evaluation of studies on emissions, meteorology and radiation exposure of wildlife prepared since then. Targeted sampling examinations conducted in 2024 enabled the further investigation of the current radiological status of wildlife. Thus, within the framework of the SSLE of the Paks NPP, the examination of radiation exposure of living organisms as well as the estimation of future risks were carried out in accordance with international recommendations.

The sensitivity of living organisms to ionizing radiation varies within very wide limits, which is why all living organisms, from the simplest community organisms to mammals, were included in the assessment. According to research based on the international recommendations and scientifically sound estimates, the dose rate without effects can be set at 10 $\mu\text{Gy/h}$ for a wide range of living organisms. Therefore, taking a conservative approach, this dose rate of 10 $\mu\text{Gy/h}$ was considered for the wildlife included in the survey. As long as the dose rate remains below this value for the wildlife, no radiation-related effects are expected.

The Paks NPP Emission Monitoring Laboratory continuously measures the plant's airborne emissions. This data was used to estimate radiation exposure to wildlife in connection with specific habitats. Based on the results, it can be concluded that the power plant's contribution to wildlife is practically negligible, i.e., it poses a neutral effect compared to global and Chernobyl-related radiation exposure, considering that it represents a significantly smaller dose contribution in comparison with global background radiation.

Estimates for the future are cut short by the predictability of expected emissions. It can be assumed that atmospheric emissions will not change significantly during the period of the continued service life. Taking discharges in the Danube into account, the continued operation of the power plant will not result in significantly higher release quantities. No significant increase in radiation exposure of the wildlife is expected, even though, in theory, isotopes with long half-lives could accumulate in the soil as a result of regular discharges. This is because the contribution of the power plant to such soil contamination is negligible compared to the current residuals of past global and Chernobyl contamination, so the total accumulation will continue to show a decreasing trend even during the prolonged operation.

The background radiation exposure of wildlife from natural sources, depending on species and habitat, ranges from a few tenths of $\mu\text{Gy/h}$ to a few $\mu\text{Gy/h}$. The estimated contribution of the power plant to the radiation exposure of terrestrial and aquatic wildlife amounted to a value between only 10^{-3} $\mu\text{Gy/h}$ and 10^{-6} $\mu\text{Gy/h}$. This negligible increase will remain even during the continued operation of the Paks NPP, as the volumes of atmospheric and aquatic emissions are not expected to change. After the termination of power generation and the production of liquid radioactive waste, this minor radiation exposure to aquatic life will disappear, while for terrestrial life it will significantly drop as the fission and corrosion products with longer half-lives accumulated in the soil decay. During the period of the SSLE, the dose exposure to the wildlife will remain at the current neutral level posing no impacts.

It has been determined that, with regard to atmospheric emissions, the Paks NPP, will not have an impact on the terrestrial wildlife during the SSLE, even when combined with the emissions from the Paks II NPP that is, its impact can be assessed as neutral.

Speaking about emergency events, no significant impact on the surrounding wildlife is expected as a consequence of such potential emergencies.

Overall, it was determined that 90-99% of the dose rate affecting the wildlife in the vicinity of the Paks NPP originates from natural sources. The dose contribution attributable to the operation and emissions of the Paks NPP is negligible, has a neutral effect and does not pose a risk of any significant magnitude to living organisms. The radiological impacts on wildlife have always been of a negligible magnitude and this is expected to remain the case for the period of the SSLE. This conclusion also applies to the concurrent operation of the two power plants.

3.3.5. Generation and management of radioactive waste and spent fuel

During the operation of a NPP, solid and liquid radioactive waste of low and intermediate activity is generated, which is temporarily stored at the NPP until it is transported to a final repository. Most of the solid radioactive waste is placed in 200-liter steel drums in a compacted, or – in the case of non-compactable waste – in an uncompacted form.

Liquid radioactive waste is collected in tanks at the NPP. Radioactive waste can only be disposed of in solid form, so liquid waste is also solidified at the NPP prior to transfer to the final repository.

The generation of radioactive waste must also be calculated with as a result of certain reconstruction works planned in frame of preparations for the SSLE, as well as of activities and modifications planned for the continued operation. Based on the estimates made, reconstruction work typically involving the NPP's architectural structures, technological systems and equipment results in the generation of radioactive waste.

In the case of reconstruction work performed in the controlled area, the total amount of waste generated is conservatively considered as radioactive waste. However, based on operational experience, a significant portion of the generated waste can be exempted. Taking practical experience and theoretical considerations, it can be assumed that a significant portion of the generated waste will be eligible for exemption under normal exemption procedures, or individual exemption permits and once removed from the controlled area, can be treated as conventional waste. The expected volume of low- and medium-level radioactive waste generated during preparatory work will be around 375 tons (~1,750 drums), of which approximately 1,000 drums will be generated between 2030 and 2032. High-level radioactive waste is expected to be generated from equipment inside the reactor, in a quantity of nearly 50 tons.

The collection, classification, management and preparation for transport and final disposal of radioactive waste generated during preparations for the SSLE are planned in accordance with the NPP's current procedures and integrated into existing management processes.

As a result of the normal operation of the NPP, approximately 90 m³ of low- and intermediate-level solid radioactive waste (approximately 450 pieces of 200-liter drums) is generated annually, to which an additional 10 m³ (50 drums) is expected from the operation of the liquid waste processing technology. Thus, 500 drums are expected to be generated annually.

According to current estimates, the volume of additional radioactive waste to generate during the 20-year extended service life period – following the conditioning of operational radioactive waste – to be disposed of in final disposal will increase from the current approx. 14,000 m³ with nearly 3,000 m³ to an aggregate 17,000 m³.

At the NPP, so-called compact waste packages will be produced from low- and intermediate-level radioactive waste using cementation technology, which is scheduled to become operational in 2029. In these packages, four 200-liter metal drums are placed into a thin-walled, reinforced steel container (*Figure 3.3.5-1.*). The space between the drums is filled with cement slurry mixed with liquid radioactive waste, so even the empty space within the containers is filled with radioactive waste.



Source: PURAM website (rhk.hu)

Figure 3.3.5-1. Compact waste package containing low- and intermediate-level radioactive waste, produced using a steel container

Activities related to the final disposal of radioactive waste and the interim storage of spent fuel fall within the responsibility of PURAM, the body designated by the Government. The final disposal of low- and intermediate-level radioactive waste is arranged at the National Radioactive Waste Repository (NRWR) (*Figure 3.3.5-2.*), an underground storage vault-based facility operated by the PURAM. Following the production and quality assurance procedures, the compact waste packages are transported from the NPP to the NRWR operated by PURAM. The final disposal of radioactive waste takes place in storage vaults excavated underground at a depth of 200-250 m.



Figure 3.3.5-2. Surface facilities of the Bataapati National Radioactive Waste Repository (NRWR) and its first filled storage vault

The total capacity of the Bataapati NRWR, with the storage vaults to be constructed according to the original plans, provides sufficient space for the low- and intermediate-level radioactive waste generated in the 50-year (30+20) service life of the Paks NPP and its subsequent decommissioning. The final disposal of low- and intermediate-level solid radioactive waste to generate during the SSLE of the NPP can be ensured by a subsequent expansion of the storage capacity at the NRWR.

A total of 1,114 storage tubes, representing 222.8 m³ of storage capacity, are available at the NPP for the disposal of high-level radioactive waste generated during operation. Out of the 222.8 m³ storage capacity, 112.7 m³ had been utilized as of 1st January 2025. Over the past 15 years, the average annual volume of high-level waste generated was 1.4 m³ per year, so conservatively, an additional 22 m³ of high-level radioactive waste is expected to be generated by the end of the 50-year operating period. Consequently, nearly 85 m³ of storage capacity is available for the interim storage of high-level waste generated during the period of preparation for and implementation of the SSLE.

The volume of high-level waste, containing low- and intermediate-level components as well, that can be stored in storage tubes can be significantly reduced through fragmentation, thereby releasing a significant portion of the capacities of the storage tubes used for their storage, approximately 40 m³ of storage capacity can be gained. The storage capacity thus saved ensures that the interim storage of high-level waste generated over the total operating period of 70 years – including the additional 20-year service life extension – is also resolved.

The high-level waste is collected in containers which are filled up with concrete for final disposal. Taking into account the rate of generation of high-level radioactive waste, the issue of final disposal, as specified in the technical plan, need only be addressed during the decommissioning phase of the NPP.

According to broad international consensus, the final disposal of high-level waste can be safely addressed in a deep geological repository. This is a facility constructed hundreds of meters underground, protected from surface influences and processes, where long-term safety is guaranteed, not only by man-made technical structures, but also by the stable geological environment. Agreement is also evident among the relevant international organizations that a deep geological repository is suitable for both the direct disposal of spent nuclear fuel and the disposal of residues from reprocessed spent fuel.

In Hungary, the research program to identify potential storage sites began in late 1993 with the investigation of the Bodai Claystone Formation in open shafts of the Mecsek uranium mine. Research aimed at the final disposal of high-level radioactive waste is currently ongoing. In 2018,

PURAM compiled the site exploration framework program for the Bodai Claystone Formation, which outlines the tasks till 2032. According to the planned schedule, the storage facility will become operational in 2064.

Spent fuel generated at the Paks NPP is placed in an interim storage facility, the SFISF, for an extended period (currently 50 years), until a decision is made regarding its reprocessing or final disposal.

According to the current plans by PURAM, the construction of the SFISF using approved modular vault dry storage (MVDS) technology, comprising 33 vaults, will ensure the interim storage of spent fuel assemblies generated during the 50-year (30+20) service life of the Paks NPP.

PURAM examined alternatives for the management of the SSLE of the Paks NPP and the spent fuel from the Paks II NPP, taking into account several factors, including the commissioning of the new Paks units. As a result of these studies, a decision was made in November 2025 to implement the interim storage of spent fuel assemblies generated during the SSLE by switching to container-based technology. From the perspective of the technology, this means that the preparation of the container as a storage unit for storage is performed using the power plant's systems, within the NPP itself. Afterward, the container, in its sealed and hermetically insulated state, simply needs to be transported to the SFISF storage site.

During the examination of the possibilities for transitioning to the container-based technology, the possibility arose of applying a new interim storage technology proposed by one of the potential suppliers, which is even more suitable in terms of the conditions at the Paks site than the other container-based technologies examined so far. The basis of the technology – taking the preparation of spent fuel assemblies for storage – is identical to the container technologies examined, with the difference that interim storage takes place not on the ground surface in a building, but in a ventilated concrete structure built underground. The technology, developed more than 10 years ago and evidenced by suitable reference facilities, is Holtec International's HI-STORM UMAX system.

From an environmental perspective, in the case of transiting to the new storage technology, the emissions associated with drying the spent fuel assemblies for storage are not related to the SFISF but to operations carried out at the NPP, specifically in the reactor hall. These emissions are already significantly below the limit value with the currently applied SFISF technology and it is expected that with the new technology, the emissions – even if not by a significant margin – will be even more favorable. Based on the analyses conducted regarding the spent fuel management activities, it can be concluded that the analyses and findings relevant to public radiation exposure also apply to the use of the Holtec HI-STORM UMAX technology.

The planned technology ensures the interim storage of spent fuel to be generated during the additional 20-year service life within the current SFISF site, so interim storage does not require the occupation of additional land. An additional advantage of the selected technology is that, while keeping environmental impacts low, it can serve as an alternative to the ground surface container-based storage building technology currently selected in the plans for the Paks II NPP.

4. Decommissioning of the NPP

The decommissioning of the NPP is the final phase of the facility's existence, beginning with the termination of operational activities necessary for the electricity generation process. The term decommissioning refers to the administrative and technical measures implemented to terminate the partial or full regulatory oversight of the facility.

The purpose of decommissioning is to dismantle the designated portion of the power plant and to restore the site to its original condition, which includes remediating both the facility and the site of radioactive contamination, dismantling structures, removing built infrastructure, removing the generated waste as well as performing all monitoring activities that verify the implementation of the decommissioning activities in accordance with approved plans.

The planning, preparation and regulatory licensing of NPP decommissioning are processes governed by law. Pursuant to Act CXVI of 1996 on Nuclear Energy, the nuclear safety licensing

and oversight of activities related to the termination of service and decommissioning of a NPP fall within the jurisdiction of the HAEA. Pursuant to OAH Decree 1/2022. (IV. 29.) on nuclear safety requirements and related regulatory activities – also detailing the requirements for decommissioning – HAEA authorization is required for decommissioning.

The license holder of the NPP prepares a so-called Preliminary Decommissioning Plan, which is continuously updated during the period of its operation and submitted to the HAEA for informational purposes following each revision. The decommissioning plan is revised every five years to account for and appropriately track changes that have occurred at the NPP. The assessment of the environmental impacts based on the current version of the plan is also incorporated into the revision.

Pursuant to Act CXVI of 1996, PURAM – the entity designated by the Government – is responsible for the final disposal of radioactive wastes, the interim storage of spent fuel assemblies and the closure of the nuclear fuel cycle, beside performing tasks related to the decommissioning of nuclear facilities.

The termination of the NPP (decommissioning) is an activity subject to a separate environmental impact assessment pursuant to Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and the integrated environmental licensing procedure. Accordingly, a separate environmental impact assessment must be prepared for the decommissioning activities, and an environmental license must be obtained from the competent environmental authority. A detailed analysis of the decommissioning activities and their expected impacts, as well as the identification of necessary environmental protection measures – including the method for post-decommissioning environmental monitoring – will be the task of the separate environmental impact assessment for the decommissioning of the NPP. This must be prepared and submitted for approval by the organization responsible for decommissioning at the end of the extended service life, prior to the decommissioning process.

5. Summary of the environmental impacts and their territorial extent

The basic assumption underlying the assessment of the environmental impacts associated with the SSLE is that the current environmental impacts and impact processes related to the NPP will continue to be decisive in the future, therefore the currently existing factors must be taken into account. However, their “service” duration will be extended by the 20-year period of continued operation. The operation of the alternative warm-water channel and cooling cell peak cooling system planned for the period of the SSLE will result in only partial and limited changes in environmental impact factors compared to previous conditions.

Based on the environmental impact assessment, which relies heavily on the evaluation of data and monitoring results reflecting the environmental impacts experienced during the Paks NPP’s operation to date and, which takes into account the expected effects of the modifications planned as part of the preparations for the SSLE, it can be concluded that no environmental, nature conservation, or landscape protection constraints have been identified that would preclude the planned SSLE of the NPP.

The total impact area, which comprises the combined impact areas of individual environmental elements and systems, affects the settlements listed in *Table 5-1*. The total impact area associated with the SSLE is the 6-17 km radius surrounding the site – as shown in *Figure 5-1*. – which extends to the territories of 10 additional settlements beyond the administrative territory of the city of Paks, where the activity is particularly registered.

Table 5-1. Settlements affected by the full impact area of the environmental impacts expected to result from the Paks NPP SSLE

No.	Settlement	Classification	District	Area [km ²]	Population [people]	Population density [people/km ²]
Tolna County						
1.	Dunaszentgyörgy	Village	Paks	37.63	2,434	65
2.	Fadd	Large village	Tolna	67.54	4,012	59
3.	Gerjen	Village	Paks	36.28	1,151	32
4.	Paks	City	Paks	154.08	17,827	116
5.	Pusztahencse	Village	Paks	31.71	917	29
Bács-Kiskun County						
6.	Bátya	Village	Kalocsa	33.86	1,830	54
7.	Dunaszentbenedek	Village	Kalocsa	23.24	714	31
8.	Foktő	Village	Kalocsa	31.46	1,409	45
9.	Géderlak	Village	Kalocsa	18.94	874	46
10.	Ordas	Village	Kalocsa	16.31	427	26
11.	Úszód	Village	Kalocsa	24.46	846	35

Source: Hungarian Central Statistical Office (HCSO) Census 2022

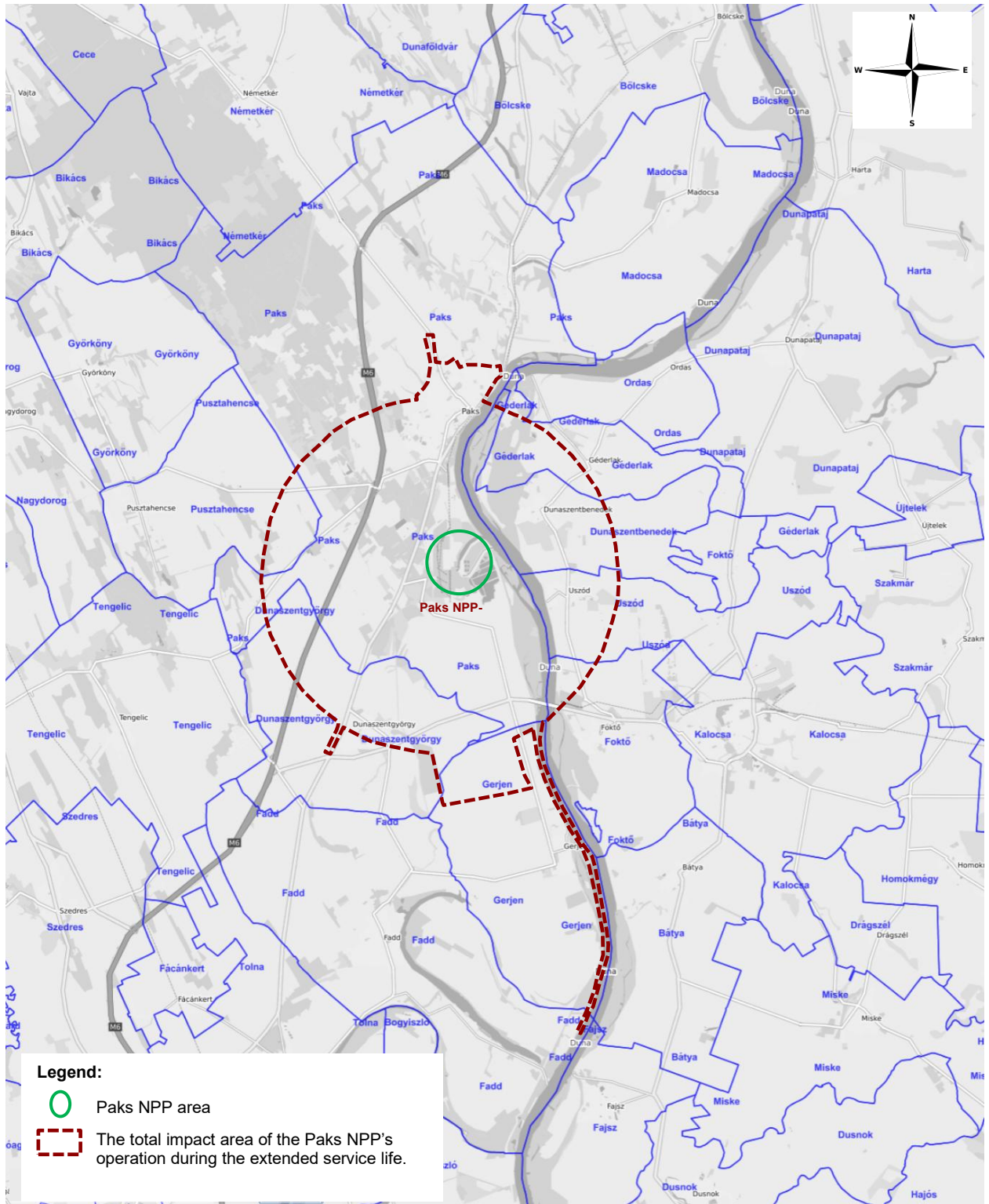


Figure 5-1. The total impact area of environmental impacts resulting from the operation of the Paks NPP and the settlements affected by the impact area for the period of the ESLE

6. Assessment of potential transboundary environmental impacts

The operation of NPPs is governed by the Espoo Convention on Environmental Impact Assessment in a Transboundary Context and the Directive 2014/52/EU (16 April 2014) of the European Parliament and Commission, which amends Directive 2011/92/EU (13 December 2011) on the assessment of the effects of certain public and private projects on the environment. The mandatory application of the Espoo Convention in Hungary is prescribed by the Government Decree 148/1999. (X. 13.) on the promulgation of the Convention on Environmental Impact Assessment in a Transboundary Context, signed in Espoo (Finland) on February 26, 1991.

An impact shall be considered transboundary if its area of impact, which causes a significant, permanent change or a long-term deterioration of conditions, extends across the national border. In the case of activities falling under the scope of the Convention, countries that consider themselves affected may request the conduct of an international impact assessment procedure regardless of, whether the area of impact extends to the given country based on the analyses conducted.

As part of the studies and analyses conducted to support the environmental impact assessment for the planned Paks NPP SSLE – based on impact processes and the sensitivity of the areas – the possibility of transboundary spread of the identified environmental impacts was examined for all possible conventional and radiological impacts and the significance of any potentially transboundary impacts was assessed. For all impact factors, an assessment was performed of impacts that might potentially cross the national border, with regard to air quality, surface and subsurface waters, the geological environment, biota and ecosystems, noise and vibration conditions and environmental radiation conditions.

Significant conventional or radiological transboundary impacts – arising from airborne or liquid emissions – could not be identified, either during normal operation of the Paks NPP or in the event of abnormal emergencies or malfunctions.

Due to the geographical location of the Paks NPP's far from national borders (at least 63 km straight and 94 km downstream along the Danube), transboundary impacts can only occur in the case of thermal loads on the Danube or events beyond the design basis of the plant. None of these impacts can be classified as significant.

The quantification of transboundary impacts related to the thermal load was performed using a multi-step, iterative modelling methodology which, in addition to examining the current state, also allowed for the prediction of future conditions, taking into account the impact of the Paks II NPP coming on line. Building on the results of climate models, a watershed-scale hydrological model was established for the entire Danube river system. Taking into account the water-flow data and the meteorological conditions, a model of future changes in the Danube's water temperature was also developed.

According to the calculations, the lateral mixing of the warmed water becomes nearly complete across the entire cross-section of the Danube over a distance of approximately 70 river kilometers. Under the current conditions, the Paks heat input causes a water temperature increase of approximately 0.4°C at the national border during normal flow conditions and about 0.9°C during low water conditions. In the future, when the current Paks units and the Paks II NPP are operating simultaneously, this effect could nearly double, resulting in a temperature increase of approximately 0.7°C at the national border during medium and 1.8°C during low-flow conditions respectively.

The assessment of the ecological impacts of the temperature increase revealed that during the concurrent operation of the Paks NPP and Paks II NPP, the extent of the impact area – calculated for the low-water condition of 2060 resulting in the largest impact area – does not exceed 18 km downstream from the Paks discharge point. Based on this, it was clearly determined that the discharge of the Paks NPP into the Danube does not cause any transboundary impacts with respect to any biological element.

In accordance with international practice regarding impact assessments for nuclear facilities, the analysis of impacts that spread across the national border included not only those resulting from operational incidents, but also events classified as "accidents" under the Hungarian terminology,

which, according to nuclear safety requirements, fall into the category of beyond design basis events.

Compliance with the extremely strict nuclear safety requirements applicable to nuclear facilities and thus to NPPs, ensures that the probability of an accident occurring is extremely low. The legal requirements for the extension of the design basis and the analysis of accidents – unlike the regulations governing normal operation and design-basis accidents – do not specify dose limits. Where necessary, they require the implementation of protective measures to reduce the radiation exposure of the public. Accordingly, the primary objective of the regulations regarding the extension of the design basis is to ensure that NPP operators as well as entities and authorities under their management are adequately prepared for the possible occurrence of events that are unlikely but have severe consequences.

In order to illustrate the potential transboundary impacts of accidents – in addition to discussing the impacts of normal operation and design basis accidents – analyses were also conducted for operating conditions beyond the design basis that could result in severe consequences in terms of emissions. Based on the results of the analyses completed, it can be concluded that no significant transboundary impacts are to be expected either in the event of severe accidents.

7. Measures to reduce and monitor the expected environmental impact during the SSLE

During the period of the SSLE of the Paks NPP, environmental compliance can be achieved primarily by ensuring the safety of the NPP. MVM Paks Atomerőmű Zrt. ensures this through continuous condition monitoring and maintenance of plant facilities and equipment, as well as through the development and implementation of maintenance and aging management programs. During the period of the SSLE, monitoring, testing, sampling and inspection activities related to the assessment of aging effects will continue, ensuring the timely identification of unexpected processes or trends of deterioration during operation, in addition to the implementation of necessary preventive and corrective measures.

The environmental protection measures, procedures and inspections already implemented and applied at the NPP are fundamentally adequate and suitable for the period of the SSLE as well, for monitoring and controlling the plant's environmental emissions and the condition of the plant's surroundings. In connection with the SSLE, it is necessary to supplement the monitoring activities with the new Danube water discharge point created by the construction of the alternative warm-water channel section, where implementation of a new measurement and water sampling site equivalent to the existing one is planned. In connection with the commissioning of the alternative warm-water channel, proposals were formulated regarding the further operation of the chemical and biological monitoring system for surface waters. To ensure an adequate environmental radiation monitoring at the Paks NPP and the Paks II NPP, the supplementation of the existing atmospheric emission monitoring system is planned.

Given that the route of the planned alternative warm-water channel section also affects the southern refuge area designated in connection with the construction works of Paks II NPP (the area to which the protected animals were relocated from the area between the cold- and warm-water channels, affected by the construction works), a new refuge area will be designated that is located near the original one, has a similar size and similar habitat conditions.

As a nature conservation measure, in order to reduce the impacts of light pollution related to the operation of the NPP, as a basic principle, efforts should be made during the design and operation of outdoor lighting to ensure that it does not disturb the natural activity cycles of birds, bats, insects and other light-sensitive organisms, and that it does not unreasonably increase the level and duration of lighting.

In the event of future legislative upgrades, significant modifications to the NPP's systems or potential changes in environmental conditions, the plant's environmental protection measures, procedures and practices will be reviewed as necessary and, where it is necessary justified, modified or supplemented.

The construction of the alternative warm-water channel section and the connected peak cooling system is considered a measure aimed at reducing the future environmental impact, since it provides the opportunity to reduce the temperature of the Danube water used for cooling at the NPP prior to its discharge to the river. Operating the peak cooling system will make it possible to reduce the thermal load on the Danube during critical periods.

In other respects, taking into account the available results regarding the monitoring of environmental impacts caused by the NPP in operation for several decades, the conclusions of this environmental impact assessment and the regulations already in place at the NPP – further measures to avoid, prevent, or reduce potential strain, disturbance, pollution – have not been identified.

Abbreviations

ASNR	Autorité de sûreté nucléaire et de radioprotection – The French Nuclear Safety and Radiation Protection Authority
BCGO	Baranya County Government Office
BME NTI	Institute of Nuclear Techniques of the Budapest University of Technology and Economics
CfD	Contract-for-Difference
CHF	Swiss franc
dB	Decibel
EG	Electrofishing gear
EIAR	Environmental Impact Assessment Report
EmMR	Emission Monitoring Regulations
EnMR	Environmental Monitoring Regulations
EPR	European Pressurised Reactor
EQR	Environmental Quality Ratio
ESD	Electric sampling device
EU	European Union
EUR	Euro
GDP	Gross Domestic Product
GWh	Gigawatt-hour
ha	Hectare
HAEA (OAH)	Hungarian Atomic Energy Authority
HI-STROM UMAX	Holtec International Storage Module Underground Maximum Security
HCSO	Hungarian Central Statistical Office
kV	Kilovolt
LTO	Long-term operation
MEKH	Hungarian Energy and Public Utility Regulatory Authority
MPC	Multi-Purpose Canister
mSv	Millisievert
MVDS	Modular Vault Dry Storage
MW	Megawatt
MW _{th}	Megawatt (thermal)
NECP	National Energy and Climate Plan
NPP	Nuclear Power Plant
NRWR	National Radioactive Waste Repository
nSv	Nanosievert
nSv/h	Nanosievert per hour
PAH	Polycyclic Aromatic Hydrocarbons
Paks NPP	Paks Nuclear Power Plant
Paks II NPP	Paks II Nuclear Power Plant
PURAM	Public Limited Company for Radioactive Waste Management
PWR	Pressurized water reactor
RBMP	River Basin Management Plan
SEK	Swedish krona
SFISF	Spent Fuel Interim Storage Facility
SLR	Subsequent License Renewal
SSLE	Subsequent Service Life Extension
TPH	Total Petroleum Hydrocarbons
TPH-GC	Total Petroleum Hydrocarbons by Gas Chromatography
TWh	Terawatt-hour
US NRC	United States Nuclear Regulatory Commission
ÜKSER	Operational Environmental Radiation Monitoring System
VVER	Water-cooled, water-moderated energetic reactor
WFD	Water Framework Directive
μGy	Microgray
μGy/h	Microgray per hour
μSv	Microsievert