ENVIRONMENTAL IMPACT ASSESSMENT REPORT

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PAKS NUCLEAR POWER PLANT SUBSEQUENT SERVICE LIFE EXTENSION



MVM Paks NPP

CONTRIBUTORS

	Organisation	Name
Compiled by	AFRY ERŐTERV ZRt.	Rozália Gátiné Magyar Péter Hayer Tamás Romenda
Prepared by Site characterisation	AFRY SOM System Kft.	Anita Puskás Márk Lehoczki Dr. László Tóth (GeoRisk Kft.) Tamás Siklóssy (NUBIKI Kft.)
Prepared by Geography, climate-meteorology, socio-economic analyses	HUN-REN CSFK	Dr. Zoltán Szalai Dr. Annamária Uzzoli Dr. József Lennert Dr. Zoltán Barcza, Dr. Tímea Kalmár
Prepared by Air quality protection	MVM ERBE Zrt.	Emőke Nagyné Juhász Dávid Pintér
Prepared by Surface and groundwater protection, protection of geological medium, waste management	NATURAQUA Zrt.	Tamás Kerékgyártó Tímea Budai, Zsuzsanna Czinkota, Gergely Kristóf, Balázs Kovács, György Maján, Péter Nagy (Kék Csermely Kft.) Borbála Rita Halasi-Kovácsné Benkhard, PhD (SCIAP Kft.) Andor Hajnal (Isotoptech Zrt.)
Prepared by Hydrology-meteorology	BME	Dr. Gábor Fleit Márk Honti
Prepared by Wildlife and nature conservation	BioAqua Pro Kft.	Dr. Béla Kiss Dr. Zoltán Müller, Judit Pócsik, Dr. Gergely Gulyás
Prepared by Noise and vibration protection	MVM ERBE Zrt.	Emőke Nagyné Juhász Dr. Zsófia Fehér
Prepared by Landscape protection, municipal environment	ÖKO Zrt.	Emőke Magyar Márton Szappanos, Dr. Endre Tombácz
Prepared by Environmental radioactivity	SOMOS Kft.	Dr. Gábor Nagy Dr. Máté Solymosi, Krisztina Kristóf
Prepared by Radiation exposure of biota	Isotoptech Zrt.	Dr. Róbert Janovics Mihály Veres, Dr. Zoltán Dezső, Dr. László Rinyu
Prepared by Radiation protection, radiation exposure of the public	HUN-REN EK	Dr. Csilla Rudas Dr. Dorottya Jakab, Zsófia Rékasi, Dr. Annamária Pántya, Barbara Brockhauser
Prepared by Human health	V-MED Bt.	Prof. Dr. János Sándor
Controlled by	MVM ERBE Zrt.	Réka Simon
Controlled by	AFRY SOM System Kft.	Mihály Kunner
Approved by	MVM ERBE Zrt.	Gábor Halász

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1. Introduction

1.1. Background

The Paks Nuclear Power Plant (Paks NPP) is a defining baseload unit of the Hungarian electricity system. Its primary function is power generation. Operated by MVM Paksi Atomerőmű Zrt., the NPP consists of four VVER-440/V-213 type reactor units, which were commissioned between 1982 and 1987. The nominal electrical capacity of Paks NPP is currently 2,026.6 MW. With an annual output of nearly 16 GWh, the plant plays a pivotal role in Hungarian electricity generation, accounting for more than 40% of the total production.

Paks NPP operates as a baseload power plant with a relatively constant load. Once-through cooling is utilised for cooling purposes in the turbine condensers associated with the four units of the plant. The required volume of cooling water is abstracted from the River Danube by the pumps of the plant's water intake structures, and the heated cooling water is discharged back into the river via the warm-water channel. The electricity generated at the plant is fed into the national grid at voltage levels of 400 kV and 120 kV, respectively.

In accordance with the climate policy objectives of the European Union, the target is to achieve climate neutrality within the Union by 2050, a commitment that all Member States have reaffirmed and remain firmly dedicated to its implementation. Nuclear energy and renewable energy sources are capable of carbon-free electricity generation. The role of Paks NPP is instrumental in achieving Hungary's climate neutrality targets.

Since the commencement of its operation, numerous safety enhancement measures and modernisation programs have been implemented at Paks NPP, the most significant of which were the following:

- The AGNES (Advanced General and New Evaluation of Safety) project (1991-1994),
- safety enhancement program (1996-2002),
- seismic hazard assessment and reconstruction (1993-2002),
- reactor protection system refurbishment (1993-2004),
- severe accident management (2008-2014),
- measures resulting from Targeted Safety Reassessments (2011-2024).

In the early 2000s, in line with international trends, MVM Paksi Atomerőmű Zrt., involving technical-scientific and economic support institutions, began assessing the feasibility of extending the plant's service life, which was originally designed for 30 years. Findings of the detailed feasibility studies conducted established that extending the service life by at least 20 years was viable. As a result of the operational and maintenance practices applied, the robust design of structures, systems and components, as well as the numerous refurbishments and safety enhancement measures, the condition of the plant permitted safe operation beyond 30 years. The decision to implement the first 20-year service life extension was taken in 2003.

The environmental impact assessment for the first service life extension of the NPP was completed in 2006, concluding that the service life extension was environmentally feasible. The MVM Paksi Atomerőmű Zrt. was granted the environmental license to operate the Paks NPP's units for further 20 years beyond their originally designed 30-year service life by a decision issued on 25th October 2006 by the South Transdanubian Inspectorate for Environmental Protection, Nature Conservation and Water Management, under case number 100562-023-197/06 and registration number K6K8324/06. The currently effective environmental license for the Paks NPP's units, consolidated with amendments under reference number 391-18/2017 (repeatedly amended between 2018 and 2024) was issued on a unit-by-unit basis. Corresponding to the 20-year service life extension of each individual unit, the validity of the licenses is set to expire between 2032 and 2037.

As early as 2013, during the implementation of the first service life extension project, the plant's experts began addressing the possibilities of a subsequent service life extension (SSLE) beyond the 50-year (30+20) period which is currently undergoing permitting. The analyses performed

then demonstrated compliance for 20+10 years from the onset, amounting to a total of 60 years. Thus, it was already apparent in the 2010s that the NPP possessed the necessary margins for continued operation.

In 2019, the assessment of the feasibility of a SSLE was launched within the framework of MVM Paksi Atomerőmű Zrt.'s corporate strategy. This was followed in 2020 by a baseline analysis on the legal, technical and economic feasibility, which verified the return on investment for the additional 10 years of operation considered at that time. Although the economic and climate policy benefits of a SSLE were evident, and several countries were already addressing the extension of service lives of operating NPPs from 60 to 80 years, or even from 80 to 100 years, the decision to launch the Paks project was deferred until a later date, due to changes in the originally scheduled implementation schedule of Paks II NPP.

The preparation for the service life extension of a NPP requires nearly 10 years. Considering that the service life of Unit 1 expires in 2032, the Government of Hungary decided in the summer of 2022 to prepare for the SSLE of Paks NPP, and, via a government decree, tasked the Minister for Technology and Industry with the preparation of the SSLE project of the NPP. In connection therewith, the activities necessary to establish the conditions required for the SSLE have commenced.

In September 2022, upon the request of their owner MVM Zrt., MVM Paksi Atomerőmű Zrt. established the SSLE Priority Project. The tasks to be executed within the framework of the project include conducting an environmental impact assessment (EIA), including the performance of studies in specialised fields to support the preparation of the EIA, as well as conducting the preliminary consultation and environmental licensing procedures. The project scope also encompasses technical analysis tasks aimed at the detailed condition assessment of system, structures and components of the NPP, as well as the review of current ageing management programs that detect ageing processes in a timely manner and effectively prevent or mitigate the effects of ageing, and the development of new programs if required. Based on the findings of the assessments to be conducted, the implementation program for the SSLE, along with the license applications required for the nuclear regulatory licensing procedures and their supporting documentation, will also be prepared within the framework of the project.

The service lifetime of Paks NPP as a facility is subject to the structures, systems and components that cannot be replaced or refurbished (long-lived assets), or for which the associated costs and downtime are so substantial that replacement is not rational from a technical-economic perspective.

Based on the available material testing, analysis and maintenance results, the plant's experts have concluded that no disqualifying factor or prohibitive cost expected to arise during the plant's operation extended to 70 (30+20+20) years for any of the components most critical to nuclear safety (e.g. the reactor pressure vessel or the steam generators). The safe operation of replaceable and refurbishable structures, systems and components can be sustained during the subsequent operational period by implementing the envisaged ageing management and refurbishment programs that form an integral part of the plant's operation. The assessments took into account the changes in external and internal conditions, as well as in technical-scientific knowledge, occurring over the 70-year period.

In accordance with the aforementioned – and considering international practices regarding the service life extension of NPPs – the technical and environmental assessments for the NPP's continued operation assume a subsequent 20-year SSLE, resulting in a total operating lifetime of 70 years. That duration includes the originally designed 30-year service life, the authorized and ongoing (first) 20-year service life extension, and the proposed subsequent 20-year service life extension, which is the subject of the current EIA.

Under the statutory regulations in force, it is not required to seek the National Assembly's preliminary approval in principle for the SSLE of an operational NPP. Nevertheless, the National Assembly was informed about the commencement of preparations for the previous service life extension. Therefore, the Government decided to provide the National Assembly with preliminary information regarding the commencement of activities related to the SSLE of Paks NPP. In its

Resolution 56/2022. (XII. 8.) of National Assembly on the SSLE of the existing units of the NPP, the National Assembly approved and acknowledged the SSLE of the NPP units by an overwhelming majority (with 170 votes in favour, 8 votes against, and 1 abstention), which – according to the resolution – serves the country's objectives regarding energy independence, climate protection and security of supply.

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 conducted with the involvement of the Hungarian Atomic Energy Authority and the Ministry of Energy, the document presenting the project was submitted to the European Commission Directorate-General for Energy, Unit ENER D.2 – Nuclear energy, nuclear waste and decommissioning, on 26th October 2023. Thereby, the formal notification of the SSLE of Paks NPP to the European Commission was completed. In January 2025, the Commission raised supplementary questions regarding the project, the responses to which were submitted on 9th April 2025. The procedure will conclude with the issuance of the Commission's final opinion.

Pursuant to Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures, the extension of a NPP's service life is an activity subject to a mandatory EIA, which may only be carried out in possession of an environmental license issued by the environmental authority. For the SSLE of Paks NPP, an environmental license issued to MVM Paksi Atomerőmű Zrt. is required, based on an environmental impact assessment procedure conducted by the Baranya County Government Office (BCGO), which holds exclusive jurisdiction over environmental regulatory matters concerning the NPP as a high-priority facility. The applicant must present the findings of the environmental impact assessment in the Environmental Impact Assessment Report (EIAR).

For activities subject to a mandatory environmental impact assessment, Government Decree 314/2005. (XII. 25.) provides the operator with the opportunity to conduct a so-called preliminary consultation procedure in order to learn the opinions of the environmental authority and the public administration bodies concerned, as well as the comments of the public, which may provide further guidance and criteria for compiling the EIAR that supports the environmental impact assessment procedure. The public concerned shall also include the public participating in the international transboundary EIA procedure pursuant to 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 26 February 1991.

On 26th September 2024, MVM Paksi Atomerőmű Zrt. initiated a preliminary consultation regarding the proposed subsequent 20-year service life extension of the Paks NPP's Units 1-4, with the BCGO, acting as the competent environmental authority, by filing a document (Preliminary Consultation Document) meeting the content requirements set out in Annex 4 of the Government Decree 314/2005. (XII. 25.). The purpose of requesting the preliminary consultation was to ensure that the development of the EIAR could be carried out by taking into account the opinions of the environmental authority and the involved public administration bodies, as well as comments from the public.

In its opinion ending the preliminary consultation (case number 383-100/2024, issued on 24th October 2024), the Environmental Authority established that no grounds for the exclusion of environmental permitting arose during the preliminary consultation regarding the SSLE of Units 1-4 of the Paks NPP. Furthermore, the environmental authority concluded that pursuant to point 31 of Annex 1 of Government Decree 314/2005. (XII. 25.) ("*Nuclear power plants, nuclear reactors, the service life extension of a nuclear power plant or nuclear reactor, and the decommissioning of a nuclear power plant or nuclear reactor, i.e. the final removal of nuclear fuel and other radioactive contaminated components of the facility, without size restriction*"), SSLE classifies as an activity subject to an environmental impact assessment, which may only be commenced or continued in possession of an environmental permit. The application for the completion of an environmental impact assessment procedure shall be accompanied by an EIAR compiled in accordance with the content requirements of Annexes 6 and 7 of the Government Decree 314/2005. (XII. 25.), taking into account the requirements formulated in the BCGO's

opinion concluding the preliminary consultation. The opinion formulated by the BCGO during the preliminary consultation – which encompasses the official technical position of the environmental authority, the expert opinions of the public administration bodies involved in the preliminary consultation, and the comments from the public – is summarised in *Chapter 1.2*.

Considering 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 adverse transboundary impacts, the foreign interested parties presumably affected have been notified – in accordance with the provisions prescribed for international environmental impact assessment procedures in Government Decree 314/2005. (XII. 25.) – in order to ensure the opportunity for consultation. The ministry in charge of environmental protection is responsible to liaise with foreign interested parties.

The BCGO informed the competent Ministry of Energy about the commencement of the preliminary consultation, thereby enabling the parties presumably affected across state borders to participate in the preliminary consultation procedure at international level. On 30th October 2024, the Ministry of Energy notified 31 Parties to the Convention (the countries neighbouring Hungary, all EU Member States, as well as the United Kingdom, Norway and Switzerland).

During the preliminary consultation procedure, comments from the notified countries were received until 22nd January 2025, with feedback being provided by only 8 potentially affected parties. Austria, Latvia, Romania and Croatia indicated their intention to participate preliminarily in the impact assessment procedure, while Finland, Poland and the Czech Republic requested information on the findings of the EIA.

MVM Paksi Atomerőmű Zrt. entered into a main contractor agreement in 2023 for the execution of tasks related to the environmental permitting procedure of SSLE. To perform those tasks, an independent project organisation, managed by MVM ERBE Energetika Mérnökiroda Zrt. as the main contractor and involving the energy engineering offices AFRY SOM System Kft. and AFRY ERŐTERV ZRt., was established under the supervision of the environmental permitting work group operating within the framework of the Paks NPP's SSLE Priority Project. Expert organisations and scientific institutions in possession appropriate references were involved in conducting studies and analyses belonging to specific technical fields of the environmental impact analysis. To supervise professional environmental tasks, MVM Paksi Atomerőmű Zrt. established an Environmental Expert Board, the members of which are recognised Hungarian scientific experts in the relevant fields.

In the period 2024-2025, technical analysis tasks and feasibility studies related to the preparation of the SSLE continued within the framework of MVM Paksi Atomerőmű Zrt.'s SSLE Priority Project. As a result of these, several investments and modifications necessary for the implementation of the SSLE, which are to be taken into account from the perspective of assessing environmental impacts, were identified. Accordingly, the activities planned to be executed by MVM Paksi Atomerőmű Zrt. as part of the preparations for the SSLE were reviewed and analysed during the environmental impact assessment conducted, with regard to the significance of the expected environmental impacts and the necessity for a detailed assessment of these impacts. The expected impacts of the SSLE preparatory works and investments identified as activities with significant environmental impacts were also analysed and evaluated in this impact assessment.

This document is the EIAR presenting the findings of the EIA conducted to support the environmental licensing for the SSLE of Paks NPP, which has been developed in compliance with the content requirements set out in Annexes 6 and 7 of Government Decree 314/2005. (XII. 25.) and as formulated in the BCGO's opinion under reference number 383-100/2024 closing the preliminary consultation.

1.2. Authority opinion closing the preliminary consultation and comments from the public

The preliminary consultation on the SSLE of Paks NPP's Units 1-4, operated by MVM Paksi Atomerőmű Zrt., was initiated on 26th September 2024 at the Environmental Protection Section of the Department for Environmental Protection, Nature Conservation and Waste Management of the BCGO. On 30th September 2024, the Government Office published a public notice on the initiation of the preliminary consultation at its premises and on its website. Stakeholders were able to inspect the electronic copies of the application, the preliminary consultation document and the public notice at the Government Office's customer service desk, as well as at the offices of the town clerks of Paks, as the location of the proposed SSLE, and of further municipalities affected by the impact area as delineated in the preliminary consultation document. Comments regarding the disqualifying factors associated with the Paks NPP's SSLE and the scope of the EIAR could be submitted to the environmental authority within 21 days following the publication of the public notice. No comments from the public concerned were received by the BCGO, the Town Clerk of Paks, or the town clerks of other municipalities affected.

In accordance with the provisions of Government Decree 314/2005. (XII. 25.), and with regard to the specialized matters to be assessed pursuant to Annex 12 of said Decree, the BCGO requested the public administration bodies designated in the Annex of the Decree to provide their comments on the SSLE of Paks NPP, taking into account the information contained in the preliminary consultation document. Comments were provided by the public administration bodies listed in *Table 1.2-1.*

Table 1.2-1. Public administration bodies that provided comments regarding the specialized matters to be assessed

	Name of the public administration body	Reference number
1.	Tolna County Government Office, Department of Public Health	TOR/71/00481-2/2024.
2.	Budapest Capital City Government Office, Department for Construction and Heritage Protection, Section for Construction and Heritage Protection	BP/2602/00899-2/2024 BP/2602/00899-3/2024
3.	Tolna County Government Office, Land Registry Department, Land Registry Section 3 (Paks)	13225/2024.
4.	Tolna County Government Office, Office of the State Chief Architect	TOB/200167-2/2024.
5.	Baranya County Government Office, Department of Agricultural Affairs, Section for Forestry and Agriculture	BA/52/07513-2/2024.
6.	Hungarian Atomic Energy Authority (HAEA)	OAH-2024-06015-0004/2024.
7.	Fejér County Government Office, Department for Fire Protection, Industrial Safety and Water Regulatory Authority, Section for Water Management and Water Protection	30407/200-1/2024.ált.

To ensure a comprehensive review of the SSLE, the BCGO requested input from bodies listed in *Table 1.2-2.*, which provided their opinions on the SSLE. The comments from these consulted public administration bodies and other institutions are included as annexes to the Government Office's opinion under file number 383-100/2024.

The findings in the regulatory opinion with reference number 383-100/2024. are summarised in *Table 1.2-3.*, indicating as part thereof which chapter, or annex of the EIAR contains the presentation – detailed as necessary – of the fulfilment of the individual tasks formulated in the opinion. The table also provides information, in a concisely summarised form, about the fulfilment of the given task or requirement. To present the contents of the regulatory opinion in their entirety, the table also includes those findings that do not contain tasks to be fulfilled in the EIAR, for instance, because they state a matter of fact rather than formulating a task to be executed. In the case of the latter, the table naturally does not contain a section presenting information on fulfilment.

Table 1.2-2. Other institutions that provided comments regarding the specialized matters to be assessed

	Name of the other institution	Reference number
1.	Supervisory Authority of Regulated Activities, Department for Mining and Gas Affairs, Pécs Mining Inspectorate Section	SZTFH-BANYASZ/12100-2/2024
2.	Tolna County Government Office, Department for Environmental Protection, Nature Conservation and Waste Management	TOG/81/00166-7/2024.
3.	Lower Danube Valley Water Directorate	006648-002/2024.
4.	Central Transdanubian Water Directorate	Szfvár-004249-0006/2024
5.	South Transdanubian Water Directorate	008023-0055/2024.
6.	Danube-Drava National Park Directorate	DDNPI/2160-2/2024.
7.	Kiskunság National Park Directorate	ÁLT/1913-6/2024

The opinions of the public administration bodies that provided comments regarding the specialized matters to be assessed during the preliminary consultation are summarised in *Table 1.2-4.*, the content of which has been compiled in the same manner as that of *Table 1.2-3*.

The opinions of other institutions requested to provide a comprehensive review of the SSLE are summarised in *Table 1.2-5.*, indicating in which specialist annex or chapter of the EIAR the fulfilment of the individual requirements takes place.

Pursuant to the provisions of the Espoo Convention, the comments received from affected foreign parties notified by the Ministry of Energy within the framework of the preliminary consultation, along with the responses provided thereto, are summarised in the *International Chapter*, which forms an annex to the *Public Summary* of the EIAR.

Table 1.2-3. Summary of the regulatory opinion closing the preliminary consultation

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
I.			
1.	Regarding the SSLE of Paks Nuclear Power Plant's Units 1-4 operated by the Operator, no disqualifying factor for environmental licensing arose during the preliminary consultation based on the contents of the preliminary consultation document and the information available.	–	It does not set forth any task to be performed in the EIAR.
2.	Pursuant to point 31 of Annex 1 of Government Decree 314/2005. (XII. 25.) ("Nuclear power plants, nuclear reactors, the service life extension of a nuclear power plant or nuclear reactor, and the decommissioning of a nuclear power plant or nuclear reactor, i.e. the final removal of nuclear fuel and other radioactive contaminated components of the facility, without size restriction"), the planned lifetime extension classifies as an activity subject to an environmental impact analysis, which may only be commenced or continued in possession of an environmental permit.	–	It does not set forth any task to be performed in the EIAR.
3.	The Operator is required to attach to the application for conducting the environmental impact assessment procedure, the EIAR compiled with the contents pursuant to Annexes 6 and 7 of Government Decree 314/2005. (XII. 25.), considering the requirements formulated in Section II of this opinion.	–	It does not set forth any task to be performed in the EIAR.
4.	Pursuant to Article 7 (3) of Government Decree 314/2005. (XII. 25.), individual sections of the Environmental Impact Assessment Report may only be prepared by experts holding expert accreditation in the specific specialist sub-fields corresponding to the content requirements, based on Government Decree 297/2009. (XII. 21.) on expert activities in environmental protection, nature conservation, water management and landscape protection.	*Chapter 1.4.*	The EIAR was prepared by experts holding credentials in accordance with the referenced legislation within the specific sub-specialist fields corresponding to the content requirements. The expert accreditations of experts were verified by references to the entries in the official public registry of the Hungarian Chamber of Engineers and in the Registry of Nature Conservation and Landscape Protection Experts of the Ministry of Agriculture.
5.	The BCGO draws the Operator's attention to the fact that, pursuant to Article 7(3a) of Government Decree 314/2005.	*Chapter 1.6.6.*	The data and information presented in the documentation are fully accessible to the public. The documentation does not contain any

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
	(XII. 25.), if the EIAR contains classified data or data qualifying as a business secret, these must be attached to the application in a separate document.		restricted, separated sections (classified data or data qualifying as a business secret).
6.	Furthermore, the application must be accompanied by the payment slip or a copy thereof proving the payment of the administrative service fee specified in Point 8.2 of Annex 2 of Decree 14/2015. (III. 31.) FM on administrative service fees for environmental and nature conservation regulatory procedures ("Nuclear power plant, nuclear reactor, as well as the service life extension of a nuclear power plant or nuclear reactor, and the decommissioning of a nuclear power plant or nuclear reactor, i.e. the permanent removal of nuclear fuel and other radioactive substance-contaminated components of the facility").	–	It does not set forth any task to be performed in the EIAR.
7.	Pursuant to Article 5/B (8) of Government Decree 314/2005. (XII. 25.), the Operator may submit an application for conducting the procedure to obtain the environmental license within two years following the issuance of this opinion.	–	It does not set forth any task to be performed in the EIAR.
II. Requirements for the Environmental Impact Assessment Report			
1.	**From the perspective of noise and vibration protection**		
1.1.	The noise protection section of the EIAR must be prepared in accordance with the provisions of Point 6.7 of the preliminary consultation document, also considering the provisions of Government Decree 284/2007. (X. 29.) on certain rules for protection against environmental noise and vibration, Joint Decree 27/2008. (XII. 3.) KvVM-EüM on the establishment of environmental noise and vibration exposure limits, and Decree 93/2007. (XII. 18.) KvVM on the method for determining noise emission limits and monitoring noise and vibration emissions.	*Chapter 4.9.* *Annex 9.*	The noise protection section of the EIAR was prepared in accordance with the provisions of Point 6.7 of the Preliminary consultation document and pursuant to the provisions of the referenced legislation. Their detailed description is contained in the referenced EIAR annex and EIAR chapter.
1.2.	The noise protection section must provide the magnitude of the noise exposure at each assessment point originating from Units 1-4 of Paks NPP, as determined by environmental	*Chapter 4.9.* *Annex 9.*	The noise protection section of the EIAR presents the findings of the environmental noise measurements conducted at the assessed points, the noise exposure values expected in the SSLE period

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
	noise measurements, and must identify the direct and indirect impact areas of the site, which need to be mapped on a valid regulatory zoning map. If it can be established that the direct impact area of Units 1-4 of Paks NPP overlaps with an area, building or room protected from a noise protection perspective, then noise emission limits for the noise sources becomes necessary to be established.		determined by model calculations, and the impact areas from a noise protection perspective. Based on the noise measurements conducted at the assessment points, the operational noise exposure at remote protected properties is so low relative to the background noise that it cannot be detected. Therefore, non-measurable low exposure values were determined using a noise model. The model calculated the noise exposure of remote points based on field measurement data close to the noise sources. The direct and indirect impact areas have been identified. In the current state, the establishment of noise emission limits for MVM Paksi Atomerőmű Zrt. is not required, as the impact area of Paks NPP does not affect any critical protected property. Regarding future developments, an application must be submitted following commissioning if it is justified by the monitoring of noise exposure. Following the implementation of Paks II NPP, Paks NPP and Paks II NPP must jointly comply with the limits.
2.	**From the perspective of air quality control**		
2.1.	With regard to non-radioactive air pollution, it is required to assess the lifetime, reliability and air pollutant emissions of the safety diesel generators associated with air pollution stationary sources P3, P4, P5, P6, P7, P8 (consisting of 1 unit per stationary source of 15 D100 type (two-stroke) diesel engines with a nominal thermal input of 4502 kW each), as well as of the safety diesel generators associated with air pollution stationary sources P9, P10, P11, P12, P13, P14 (consisting of 1 unit per stationary source of PILSTICK type (four-stroke) diesel engines with a nominal thermal input of 6285 kW each), taking into account from the perspective of the service life extension the provisions of Decree 53/2017. (X. 18.) FM on the operating conditions and emission limits of air pollutants for combustion plants with a total rated thermal input of 140 kW_{th} or more but less than 50 MW_{th}, including its requirements applicable from 1st January 2030.	*Chapter 2.2.2.2.* *Chapter 4.1.* *Annex 1.*	The air pollutant emissions of the safety diesel generators are assessed by the referenced air quality protection section of the EIAR using atmospheric dispersion model calculations. The plans regarding the condition and continued operation of the diesel generators are presented in *Chapter 2.2.2.2.* of the EIAR. Regarding the air pollution stationary sources associated with the diesel generators, the air pollutant emission limits have been detailed for both the current period and the period after 1st January 2030. The emission limits were determined based on Decree 53/2017. (X. 18.) FM according to the provisions of said Decree effective until the end of 2029 and from the beginning of 2030.

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
2.2.	If a full or partial replacement of the engines associated with the safety diesel generators is required, the relevant plans must also be presented and their impacts assessed.	*Chapter 2.2.2.2.* *Chapter 4.1.* *Annex 1.*	Information regarding the planned replacement of the safety diesel generators and the installation of the backup safety diesel generator is presented in *Chapter 2.2.2.2.*; the expected environmental impacts are evaluated in the referenced air quality protection section of the EIAR, which also details the relevant environmental requirements.
3.	**From the perspective of geological medium protection**		
3.1.	The environmental impact assessment must be submitted with regard to Annex 4 of Government Decree 219/2004. (VII. 21.) on the protection of groundwater.	*Chapter 4.4.* *Annex 4.*	Corresponding to the statutory structure and the relevant content requirements applicable to the activity under review, the assessment of impacts on the geological medium is described in *Annex 4*, while the findings of the assessment are summarised *in Chapter 4.4*. The discipline-specific annex contains all relevant analysis and assessments prescribed in Annex 4 of Government Decree 219/2004. (VII. 21.) Contamination of the geological medium and groundwater has occurred, and could potentially occur, solely in connection with emergency events. The assessment of such events also covered the analysis of contaminant propagation processes, as well as human health and environmental risks.
4.	**From the perspective of environmental radiation protection:**		
4.1.	Please state whether you intend to continue applying the atmospheric and liquid discharge limits derived from the previously established dose constraint of 90 µS/year. Furthermore, please submit the document on the determination of discharge limits for the Paks NPP's Units 1-4 as an annex to the environmental impact assessment report.	*Chapter 5.1.1.*	Based on the justification presented in *Chapter 5.1.1.*, MVM Paksi Atomerőmű Zrt. intends to continue applying the atmospheric and liquid discharge limits derived from the 90 µS/year doseconstraint. As a result of keeping the discharge limits for atmospheric and liquid releases unchanged, the documents submitted to and approved by the environmental authority to substantiate such limits remain valid, the details of which are set out in *Chapter 5.1.1*.
4.2.	Please present in detail all potential radioactive atmospheric and liquid discharge pathways, modes, and points with respect to the operation of the Paks NPP's Units 1-4.	*Chapter 5.1.1.*	With respect to the operation of the Paks NPP's Units 1-4, the potential radioactive atmospheric and liquid discharge pathways, modes, and points during the SSLE period will remain identical with the currently known and licensed discharge pathways, modes, and points.

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
4.3.	Please describe the structure and operation of the discharge and environmental monitoring system for the Paks NPP's Units 1-4. Should the refurbishment of the radiation monitoring systems affect the currently effective discharge and environmental monitoring regulations, the revision of those regulations may also become necessary.	*Chapter 2.4.2.*	*Chapter 2.4.2.*, which presents in detail the structure and operation of the discharge and environmental monitoring system for the Paks NPP's Units 1-4, addresses the issue of a potential need to modify the monitoring system in a separate subsection. Paks NPP's existing monitoring system is fundamentally adequate for the monitoring of discharges and the environment at the Paks II NPP, currently under construction adjacent to the Paks NPP, i.e. it is suitable for monitoring the combined discharges of both power plants. However, modifications are required in certain areas. Those necessary modifications are presented in the referenced chapter. The currently effective discharge and environmental monitoring regulations may be revised and amended in alignment with the construction schedule of the Paks II NPP.
4.4.	In order to fully comply with the provisions of Section 10 (1) (b) of Decree 15/2001. (VI. 6.) KöM on radioactive discharges into the air and water during the application of nuclear energy and the monitoring thereof, the operator is required to conduct a comprehensive analysis into the thermal load on the Danube, for the increasingly extreme weather conditions and the cumulative effects expected upon the commissioning of Units 5-6 to be constructed by Paks II. Atomerőmű Zrt. Furthermore, it is recommended to upgrade the operational systems associated with the thermal load, and it would also be justified to present alternative technological interventions aimed at mitigating the temperature of the water to be discharged into the Danube.	*Chapter 4.3.* *Annex 3.*	The comprehensive analysis into increasingly extreme weather conditions, the cumulative effects expected from the commissioning of the new Paks II NPP units, and specifically the thermal load on the Danube, constituted a priority area in substantiating the EIAR. Their detailed description is contained in the referenced EIAR chapter and annex. This includes the presentation and assessment of the – planned for the period of simultaneous operation with the Paks II NPP – alternative technology (namely, a peak cooling system to be installed alongside a new, alternative warm-water channel, utilizing a technology substantially identical with that planned for the Paks II NPP) whose application ensures compliance with the thermal load limits for the Danube, even under extreme weather conditions and following the commissioning of Paks II NPP. The implementation of this system is of primary importance, as its intermittent operation following the commissioning of Paks II NPP will prevent the forced electrical output curtailments experienced in recent years during hot summer periods to maintain compliance with the temperature limits of the Danube.
4.8.	Please review, update, and submit the methodology contained in the assessment "Development of the operational system associated with the thermal load of the	*Chapter 2.4.1.*	The review and update of the methodology contained in the assessment "Development of the operational system associated with the thermal load of the Paks NPP and analysis into improving

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
	Paks NPP and analysis into improving mixing", compiled in September 2010 by the Department of Sanitary and Environmental Engineering of the Budapest University of Technology and Economics.		mixing" originally compiled by the Department of Sanitary and Environmental Engineering of the Budapest University of Technology and Economics has been carried out by the university's Department of Hydraulic and Water Resources Engineering, which performed the analyses to substantiate the EIAR. The reviewed assessment has been submitted to the BCGO. In addition, the results of the update have been presented under the section "Protection of Aquatic Life in the Danube Against Thermal Load" in the referenced EIAR chapter, which points out the adequacy of the currently applied system and methodology along with their compliance with the target to be achieved.
4.9.	Please also address the case of beyond-design-basis operational states and accidents involving the presumably highest radioactive discharge, determining the anticipated transboundary activity concentration levels and expected dose values for the isotopes that are decisive with respect to the discharge.	*Chapter 8.* *International chapter*	The analyses performed to substantiate the EIAR also extended to the case of beyond design basis operational states and accidents involving the presumably highest radioactive discharge. As part of these, the presumable transboundary activity concentration levels and expected dose values were determined for the isotopes that are decisive with respect to the discharge. The analyses performed and their findings are included in the referenced *Chapter 8*, as well as in the statutory *International Chapter* of the EIAR.
5.	**From a landscape and nature conservation perspective:**		
5.1.	In respect of the proposed SSLE, the volumetric, qualitative, and thermal impacts on the Danube and its aquatic life, caused by the cooling water discharged from the warm-water channel into the river, must be investigated across the entire impact area.	*Chapter 4.3.* *Annex 3.*	The detailed analysis of the volumetric, qualitative, and thermal impacts caused by the heated cooling water discharged from the warm-water channel into the Danube was a priority area in substantiating the EIAR, taking into account the effects of climate change on the one hand, and the impacts resulting in an increased thermal load on the Danube upon the commissioning of the Paks II NPP on the other. Compliance with the statutory limits on the thermal load of the Danube will be ensured for both the Paks NPP and the Paks II NPP through the intermittent operation of a dedicated peak cooling system to be constructed specifically for this purpose. The impacts of various operational states are presented in the referenced EIAR annex and chapter.
5.2.	According to the Documentation, the riverbed material originating from dredging the cold-water channel will in future be deposited into the thalweg of the Danube via a permanent	*Chapter 4.3.* *Annex 3.*	In the water rights permit for dredging the cold-water channel, the bankside discharge of the dredged material was authorised;

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
	discharge system. In consideration of the dredging periods and the volumes of dredged material, it must be investigated what cumulative impacts the deposition of the riverbed material from dredging the cold-water channel and the proposed subsequent service life will have on the Danube and its aquatic life.		therefore, its hydrological, water quality, and ecological impacts were assessed in detail in *Chapter 6.3 of Annex 3*. The analysis extended to the hydrological, water quality, and ecological impacts of the discharge of slurry originating from the dredging of the cold-water channel. In summary, it can be established that the discharge of dredging slurry into the right bank of the Danube can be regarded as a long-term, strong, and highly significant impact. A local deterioration in the ecological condition of the groups of affected species is also anticipated up to the cross-section of the Nagy-Sarkantyú groyne, meaning that within this permanent impact area, the impact will be locally burdensome to the biological quality elements acting as receptors. At the same time, at the water body scale, and taking into account the localized extent of the impact, this shift is also expected to be tolerable for the flora and fauna communities. Although the discharge will be periodic, a detectable permanent impact area is expected to extend as far as the Nagy-Sarkantyú due to the restructuring of the sediment, but during discharge periods, the impact will be perceptible down to the lower cross-section of the Uszód side arm.
5.3.	As an appendix to the application for the environmental permit, the appropriate assessment documentation compiled pursuant to Annex 14 of Government Decree 275/2004. (X. 8.) on nature conservation areas of European community importance must be submitted in respect of the Natura 2000 site (Tolnai Duna HUDD20023) affected by the proposed service life extension.	Appendix to *Annex 6* (Natura 2000 impact assessment documentation)	The impact assessment documentation for the Natura 2000 site (Tolnai Duna HUDD20023) affected by the proposed SSLE necessitating the construction of the alternative warm-water channel and the associated peak cooling system ensuring compliance with the thermal load limits for the Danube is contained in the referenced appendix. The impact assessment documentation is compiled with the content required under the referenced statutory provisions.
5.4.	A nature conservation action plan must be developed in the event that a drastic change should occur in the aquatic life within the direct impact area during continued operation (e.g. fish mortality in the Danube).	*Chapter 4.5.1.*	The environmental impacts related to the operation of the NPP are known based on the experience of the power plant's operation over several decades and are presented in detail in the EIAR. The results of the analyses carried out for the SSLE period confirm that no changes – considering also the climate change – are expected in terms of the environmental impacts of the power plant that would represent a major difference compared to previous periods. With regard to the heat load on the Danube, the available intervention

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
			options (reducing the load on the NPP and implementing the planned peak cooling system) ensure that the limits can be met even in changing climatic conditions. Preparation of a nature conservation action plan is justified if, as a result of a significant harmful impact related to the operation of the power plant, significant destruction or degradation of a species or habitat of importance for nature conservation would be observed. However, no such significant change is expected in the environmental emissions of the NPP during the SSLE period, therefore no extraordinary event – that cannot be handled using the existing regulations and would necessitate the development of a nature conservation action plan – should arise in the future.
5.5.	Please present what biological monitoring you plan during the proposed service life extension, with particular regard to Natura 2000 qualifying species and habitats.	*Annex 3.*	*Chapter 6.8. of Annex 3* details the environmental monitoring system proposed for the SSLE period. The chapter contains descriptions of the chemical monitoring system for inspecting Danube water quality, as well as specific biological monitoring systems designed from a WFD and nature conservation perspective. While the proposed system relies on the experiences gained from the currently operated monitoring system on the one hand, it also supplements them with the findings of the analyses substantiating the EIAR on the other.
5.6.	Please, present the on-site and off-site (surrounding) ecological conditions, including a presentation of the nature conservation development of the site, with particular regard to the gradual conversion of shelterbelts and perimeter planting to native tree species, the control of invasive species (false indigo-bush, milkweed, goldenrod, etc.), and new habitat enhancements (e.g. the creation of nesting sites, installation of nest boxes, enhancement of existing habitats, professional green space management, and planting, etc.).	*Annex 6.*	The on-site and off-site (surrounding) ecological conditions (baseline status) were presented in *Annex 6* of the baseline documentation. The development of the areas within and outside the site from a nature conservation perspective is treated as a high priority task by MVM Paksi Atomerőmű Zrt. in cooperation with the licensees of the neighboring nuclear facilities, PURAM and Paks II. Atomerőmű Zrt. As part of this, emphasis is placed on ensuring that ecological and nature conservation aspects are also applied during plant planting and vegetation management works on the site and in the immediate vicinity of the site. Within this framework, it is ensured that native and local species are planted during cover and surround afforestation, as well as tree planting within the site, and that existing non-native and local tree specimens are gradually replaced

	Finding of the regulatory opinion	EIAR chapter or annex containing fulfilment of task or requirement	Summary of the fulfilment of the task or requirement
			with such species. They emphasize that they allow as little space as possible for the appearance and possible spread of alien, invasive species, since in connection with climate change, the potential appearance of new invasive species in the region, including in the vicinity of the site, is expected in the future. To meet these requirements, MVM Paksi Atomerőmű Zrt. has begun developing a green area development concept, regardless of the implementation of further operating life extension, the aim of which is to increase the water retention capacity of the area and create more complex ecological networks, in addition to the above.
5.7.	Please, assess the impacts of light pollution caused by the night-time lighting at the Paks NPP, with particular regard to the bat and insect fauna, as well as nocturnal migratory bird species.	*Chapter 4.5.* *Annex 6.*	According to the findings of the analyses conducted as part of the EIAR, a perceptible, adverse impact can also be established in respect of the impact factors arising from light pollution. However, based on the categorization under the applied impact evaluation system, the magnitude of the impact for this factor is merely minor and tolerable.

Table 1.2-4. Summary of opinions from public administration bodies that submitted observations during the preliminary consultation

Opinion from the public administration body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
1. Tolna County Government Office, Department of Public Health		
Based on the preliminary consultation documentation, no disqualifying factors have arisen in relation to the proposed SSLE; therefore, no objections are raised from a public health, environmental health or municipal health perspective. The environmental impact assessment report to be elaborated based on the recommendations made in the preliminary consultation documentation is deemed to be of sufficient detail from a public health perspective, and no further supplementation is warranted.	–	It does not set forth any task to be performed in the EIAR.

Opinion from the public administration body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
2. Budapest Capital City Government Office, Department for Construction and Heritage Protection, Section for Construction and Heritage Protection		
Regarding the preliminary consultation on the SSLE of the Paks NPP's Units 1-4 (taking into account the provisions of Section 88 of Government Decree 68/2018. (IV. 9.) on the rules concerning the protection of cultural heritage) raise no conditions from a heritage protection perspective, subject to the following comment. If the activities indicated in the long-term plan under "Planned equipment and asset replacements, refurbishments, reconstructions" entail earthworks, the heritage involvement must be individually assessed in the course of subsequent procedures.	–	In the event of activities involving earthworks (such as the construction of an alternative warm-water channel section and a peak-cooling system), the heritage involvement will be subject to examination.
3. Tolna County Government Office, Land Registry Department, Land Registry Section 3 (Paks)		
I grant my regulatory approval subject to the following conditions: − If agricultural land is used for other than agricultural purposes, which constitutes a temporary or permanent deviation from the cultivation obligation, rendering the agricultural land unfit for subsequent agricultural use, the necessary permit must be requested from the competent Land Registry, because pursuant to Section 10 of Act CXXIX of 2007 on the Protection of Agricultural Land, "*agricultural land may be utilised for other purposes solely with a permit issued by the real estate registration authority*". In the absence of such a permit, authorisations issued by other authorities shall not exempt the user from the legal consequences set forth in this Act. − The planned activity shall not impede the proper agricultural utilisation of the agricultural lands adjacent to the land parcel(s) subject to this regulatory authority procedure.	–	No utilisation of agricultural land is planned in connection with the SSLE.
4. Tolna County Government Office, Office of the State Chief Architect		
Pursuant to Point 1.13 of Annex 4/7 to Act CXXXIX of 2018 on the spatial planning plan of Hungary and certain priority regions, "Paks I" was designated as an existing NPP, and the Paks NPP is featured on the National Structural Plan (which constitutes Annex 2) with the symbol for an "(existing) NPP". Pursuant to Point 2.8.1 of Annex 1 to Municipal Decree 8/2020. (X. 29.) of the General Assembly of Tolna County Municipality on the spatial	*Chapter 2.1.2.2.*	The current use of the land occupied by the Paks NPP is consistent with the method of land use laid down in the municipal development plans. The alignment of the alternative warm-water channel section, planned to be constructed as part of the preparations for the SSLE, partly affects water management zones (fishponds, the riverbank of the Danube) according to the current zoning classification. Consequently, an amendment to the

Opinion from the public administration body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
planning plan of Tolna county, the Paks NPP is designated under the name “existing NPP”, and it is featured on the Regional Structural Plan map sheet (which constitutes Annex 2) with the symbol for an “(existing) NPP”. Based on the foregoing, conformity with the spatial planning plans is ensured.		boundaries of the industrial-economic zone designated Gip-M/PI and the water management zone designated V-6 will be required, to ensure that the warm-water channel section is situated within the building zone designated Gip-M/PI.
5. Baranya County Government Office, Department of Agricultural Affairs, Section for Forestry and Agriculture		
The Forestry Authority has reviewed the submitted documentation and established that the location of the activity is the existing site of the Paks NPP. The subject of the assessment is an existing, currently operational facility with buildings, equipment and infrastructure elements already in place, the service life extension of which does not involve the further use of forest land. Pursuant to the specific matter defined in Point 5 of Annex 12 to Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures, a precondition for examining the specific forestry matter is that the requested activity must precede the permitting of an activity implemented through the use of forest land registered in the Forestry Database or an adjacent land parcel. In light of the foregoing, and in the absence of fulfilment of the condition prescribed for the examination of the specific forestry matter, the Forestry Authority raises no observations in the course of the preliminary consultation.	*Chapter 4.6.* *Annex 7.*	The alternative technology ensuring compliance with the thermal load limit for the Danube (namely the construction of new structures and equipment for the peak-cooling system to be built alongside the alternative warm-water channel) will involve the use of green spaces and forest land in the immediate vicinity of the NPP. Pursuant to Section 82 (4) of Act XXXVII of 2009 on forests, the protection of forests and forest management, the forestry authority must prescribe compensatory afforestation if the affected management-planned forest land is: a) 0.5 ha or more in the case of natural and semi-natural forests, or b) 1 ha or more for forests under other classifications. In the present case, the planned land use affects secondary forest covering an area of 0.78 ha; therefore, compensatory afforestation is not mandatory; the land use can be implemented subject to the payment of a forest conservation contribution. Irrespective of the aforesaid, it is recommended that, in lieu of the land taken, a new forest should be planted as a protective afforestation zone within the area proposed for afforestation by the National Spatial Planning Plan (OTrT), preferably in the surroundings of the power plant.
6. Hungarian Atomic Energy Authority (HAEA)		
The contents of the preliminary consultation documentation do not contradict the effective statutory provisions governing the safe application of nuclear energy and nuclear emergency preparedness and response (Act CXVI of 1996, OAH Decree 1/2022. (IV. 29.) and Government Decree 190/2011. (IX. 19.). Pursuant to Point 1 b) of Section 17 (2) of Act CXVI of 1996 on nuclear energy, the SSLE, to be granted on a unit-by-unit basis, also requires the relevant licenses issued by the HAEA. In those procedures, the HAEA	–	It does not set forth any task to be performed in the EIAR.

Opinion from the public administration body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
enforces the requirements relating to the safe application of nuclear energy, radiological protection and nuclear emergency preparedness and response.		
7. Fejér County Government Office, Department for Fire Protection, Industrial Safety and Water Regulatory Authority, Section for Water Management and Water Protection		
According to available records, the site does not affect the protection zone of any operational or future drinking water source. Based on the 1:100,000 scale sensitivity map pursuant to Section 7(4) of Government Decree 219/2004. (VII. 21.) on the protection of groundwater, the pollution sensitivity classification of the area with respect to the status of groundwater is designated as a sensitive area (specifically under classification 2.c). The requested activity does not influence the passage of floods and ice. Adverse impacts on the runoff and status of waters can be prevented by prudent operation and compliance with the provisions of the relevant legislation. No objections have been raised and no specific requirements have been imposed from a water management and water protection perspective regarding the contents of the submitted documentation. No disqualifying factors have arisen in relation to the service life extension. According to the documentation, based on the identified impact area, no transboundary environmental effects on surface waters are anticipated; this applies even to the impacts on aquatic life resulting from the thermal load on the Danube caused by the discharge of heated cooling water during the period of simultaneous operation of all six units. No additional conditions have been set regarding the contents of the Environmental Impact Assessment Report required for the environmental permitting procedure, beyond the statutory elements prescribed by legislation.	–	It does not set forth any task to be performed in the EIAR.

Table 1.2-5. Summary of opinions from other bodies that submitted observations during the preliminary consultation

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
1. Supervisory Authority of Regulated Activities, Department for Mining and Gas Affairs, Pécs Mining Inspectorate Section		
Pursuant to Section 5/A (1) (a) of Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures, the Mining Authority, due to a lack of jurisdiction, is unable to issue a professional position statement regarding the preliminary consultation on the SSLE of the Paks NPP's Units 1-4. operated by MVM Paksi Atomerőműt Zrt.	–	It does not set forth any task to be performed in the EIAR.
2. Tolna County Government Office, Department for Environmental Protection, Nature Conservation and Waste Management		
In the fields of air quality control, noise and vibration protection, and the protection of the geological medium:		
Based on the information presented in the preliminary consultation documentation, no objections in principle have been raised regarding the service life extension; the environmental impact assessment report must be prepared in compliance with the content requirements specified in Annex 6 to Government Decree 314/2005. (XII. 25.).	*Chapter 4.1.* *Chapter 4.4.* *Chapter 4.9.* *Annex 1.* *Annex 4.* *Annex 9.*	The air quality control section is contained in *Annex 1*, and the results of the assessment are summarised in *Chapter 4.1.* The noise protection section is contained in *Annex 9*, and the results of the noise assessment are summarised in *Chapter 4.9.* The assessment of impacts on the geological medium is described in *Annex 4*, while the findings of the assessment are summarised *in Chapter 4.4*. The EIAR has been compiled in compliance with the content requirements specified in Annex 6 to Government Decree 314/2005. (XII. 25.).
In the field of waste management:		
Based on the information presented in the preliminary consultation documentation, no objections in principle have been raised regarding the service life extension; the Environmental Impact Assessment Report must be prepared in compliance with the content requirements specified in Annex 6 to Government Decree 314/2005. (XII. 25.).	*Chapter 4.8.* *Annex 8.*	The generation and management of non-radioactive waste are presented in *Annex 8*, and the results of the assessment are summarised in *Chapter 4.8*. The EIAR has been compiled in compliance with the content requirements specified in Annex 6 to Government Decree 314/2005. (XII. 25.).
In the fields of landscape and nature conservation:		
In addition to the mandatory content elements, the Environmental Impact Assessment Report documentation to be submitted must extend in particular to the following:		

	Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
1.	The impacts arising from the thermal load on the Danube affecting the aquatic life of the river, as well as the floodplain directly interacting with the river and its ecosystems shall be assessed based on updated climatological and hydrological forecasts and in relation to the proposed operational cycle. Within this framework, the environmental impacts of engineered structures not included in previous environmental impact assessment documentations (Paks I and Paks II) must also be examined in detail, specifically: the “peak-cooling system”, and the outlet recirculation system branching off upstream of the warm-water channel outlet to ensure the de-icing of the cold-water channel and emergency water make-up.	*Chapter 4.3.* *Annex 3.*	The assessment of the thermal load on the Danube is contained in *Annex 3*, and the results of the assessment are summarised in *Chapter 4.3*. To substantiate the EIAR, an assessment with the required scope was also conducted on the environmental impacts of the engineered structures not included in previous environmental impact assessment documentations (namely the Paks NPP’s first service life extension and Paks II NPP); these structures include the peak-cooling system, and the outlet recirculation system branching off upstream of the warm-water channel outlet to ensure the de-icing of the cold-water channel and emergency water make-up.
2.	The environmental impacts of the disposal of dredged material, originating from the regular dredging of the cold-water channel, into the thalweg.	*Chapter 4.3.* *Annex 3.*	The impact assessment of the disposal of dredged material originating from the dredging of the cold-water channel is described in *Annex 3*, while the findings of the assessment are summarised *in Chapter 4.3*. In the water rights permit for dredging the cold-water channel, the bankside discharge of the dredged material was authorised; therefore, its hydrological, water quality, and ecological impacts were assessed in detail in *Chapter 6.3. of Annex 3*. In summary, the discharge of dredging sludge into the right bank of the Danube can be regarded as a long-term, strong, and highly significant impact. A local deterioration in the ecological condition of the groups of affected species is also anticipated up to the cross-section of the Nagy-Sarkantyú groyne, meaning that within this permanent impact area, the impact will be locally burdensome to the biological quality elements acting as receptors. At the same time, at the water body scale, and taking into account the localized extent of the impact, this shift is also expected to be tolerable for the flora and fauna communities. Although the discharge will be periodic, a detectable permanent impact area is expected to extend as far as the Nagy-Sarkantyú due to the restructuring of the sediment, but during discharge

Opinion from other body		EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
			periods, the impact will be perceptible down to the lower cross-section of the Uszód side arm.
3.	As an independent subsection of the environmental impact assessment documentation, a Natura 2000 appropriate assessment report must also be submitted with a data content compliant with Annex 14 of Government Decree 275/2004. (X. 8.) on nature conservation areas of European community importance; and it must likewise address, as a matter of priority, the environmental impacts affecting the qualifying species and habitats of the Natura 2000 site concerned, arising from the thermal load of the River Danube and the thalweg discharge of bed material from operational dredging.	*Annex 6.*	The impact assessment documentation concerning the Natura 2000 sites is contained in the appendix to *Annex 6*. The Natura 2000 impact assessment was compiled in accordance with the prescribed criteria and the legislative requirements.
3. Lower Danube Valley Water Directorate (ADUVIZIG)			
Accepting the presented international practices according to which NPPs remain operational and safely reliable even after a lifetime extension of a greater magnitude than previously seen in Hungary, we consider it necessary to emphasize that in the matter at hand, procedures must be conducted taking into account local specificities and characteristics, and the highest level of safety must be pursued regarding both human and environmental factors. In our assessment, the Paks II NPP, to be constructed in the immediate vicinity of the facility, and its impact on the environment can also be considered as such a local specificity. Therefore, the Lower Danube Valley Water Management Directorate considers it of key importance that, during the environmental licensing procedure for the Paks NPP's subsequent 20-year service life extension, the environmental impacts of the joint operation of the existing NPP and Paks II NPP, which will be constructed and commissioned in the meantime, be presented in detail within the draft EIAR, also demonstrating the various phases of construction and joint operation.		*Chapter 1.5.2.*	The aspects to consider in relation with the environmental impacts arising from the construction of the Paks II NPP are contained in *Section 1.5.2*. The EIA was conducted in accordance with the aspects described.
Attributable to the purpose and nature of the preliminary consultation document, the conclusions and findings presented in		The relevant and affected chapters of the EIAR.	The findings made in the preliminary consultation document were in all cases based on the results of the analysis of the available

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
the material are not supported by numerical data. These must be detailed in the EIAR to ensure that the evaluation process can be followed and assessed.		data, which were not presented in detail due to space constraints. Based on the review of the scope involved as presented in the preliminary consultation document, as well as on the new analyses carried out as a basis for the EIAR, the impact assessment content was presented in detail within the EIAR in accordance with the provisions of the legislation and the regulatory opinion issued on the preliminary consultation document, including the conclusions and findings presented and the bases thereof.
We consider it important that the data presented in the EIAR are as up to date as possible, particularly considering that the environmental license sought in the current procedure will enter into force after the expiry of the previous service life extension (after 2032-2037); at the same time, accelerated changes observed recently e.g. due to the effects of climate change (such as rising temperatures and an increased frequency of extreme weather and hydrological processes) may alter the statistical evaluation results of older data. This applies particularly to the River Danube, which is affected by liquid discharges and falls under the management of ADUVIZIG, as well as to the thermal load imposed on it and, as a consequence thereof, the ecological status of the affected Danube section. The results of the monitoring activity for the period extending up to 2032-2037 may also serve the above objective, as they could further refine and fine-tune the operation of the NPP and the operational specifications and requirements in the licenses to be issued. Proceeding from the above, we also deem it expedient to review and restructure the supervisory monitoring system in such a manner that it already supports the period of the second service life extension under the term of the current license (by encompassing the components examined, the sampling locations, and frequencies).	*Annex 3.* *Annex 4.* *Annex 5.*	Information regarding the supervisory monitoring system is contained in *Appendices 3-5*. *Chapter 6.8. of Annex 3* details the environmental monitoring system proposed for the SSLE period. The chapter contains descriptions of the chemical monitoring system for inspecting Danube water quality, as well as specific biological monitoring systems designed from a WFD and nature conservation perspective. While the proposed system relies on the experiences gained from the currently operated monitoring system on the one hand, it also supplements them with the findings of the analyses substantiating the EIAR on the other.
In Section 1.5.4 (Declaration on the implementation of interconnected activities), the preliminary consultation document states that '… accordingly, no other activity of the same nature is	*Chapter 1.6.4.*	The assessment of interconnected activities is contained in *Section 1.6.4*. The EIAR and other documentation pertaining to the individual facilities examine and evaluate the cumulative

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
planned at the site of installation or on the neighbouring properties which, when aggregated with the activity assessed in the present preliminary consultation document, would reach the threshold specified for the activity under Annex 1 or Annex 3 of Government Decree 314/2005. (XII. 25.). …'. This finding is based on the premise that the Paks II NPP, which is planned in the immediate vicinity of the area, and the SFISF hold independent environmental licenses. In our view, power plants with identical activities – and thus with emissions of the same nature – cannot be treated separately from the perspective of environmental impacts, even if they are legally distinct at present, because the construction, operation and decommissioning of both must take into account the impacts of the other, directly adjacent facility.		impacts of each facility. Accordingly, the present EIAR also analyses in detail those impacts where a combined effect can be interpreted. The detailed presentation of combined effects is contained within the relevant chapters of the EIAR and the associated discipline- specific annexes.
In its subsection on site activities with an environmental impact, Section 2.1.5 of the preliminary consultation document, entitled "Site-specific external hazards of human origin and combinations of external hazards", describes that the plant is prepared to manage severe accidents involving environmental exposure. It appears expedient to enumerate and list these events in the EIAR, and to demonstrate their management based on the emergency response plans, or to provide a reference to the relevant text section.	*Chapter 2.3.* Discipline-specific annexes	MVM Paksi Atomerőmű Zrt.'s Safety Report, prepared in accordance with Government Decree 219/2011. (X. 20.) on the protection against severe accidents involving dangerous substances, contains a survey and evaluation of hazardous activities conducted at the Paks NPP's site and the presentation of the safety management system, which is referenced and briefly summarised within the EIAR. In addition, it outlines the dangerous substance necessary for the power plant's operation, which, under the terms of the above Government Decree, is to be regarded as a significant source of hazard due to its quantity. The description of emergency scenarios and the methods for their management are contained in detail within the aforementioned safety report. The operating states and emergencies potentially causing environmental exposure are described in *Chapter 2.3.* of the EIAR, while their management is described in the discipline-specific annexes.
In the section presenting the combinations of external hazards threatening the Paks NPP's nuclear safety, it is stated that 'based on the results of the assessment, the overall conclusion can be that the Paks NPP is adequately protected against the effects of combinations of design basis hazards. The available forecasts	*Chapter 2.1.4.* *Annex 3.*	In all cases, the analysis of the combinations of external hazards relied on forecasts prepared for individual hazards, which are described in the sections of the EIAR pertaining to individual hazards. As for the extremely high cooling water temperature, it could be established that a stable unit state can be ensured even

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
did not indicate any future changes on the basis of which a significant alteration of the consequences could be predicted. Consequently, the combinations of external hazards will not threaten the power plant during the SSLE to such an extent that it would have a material impact on the plant's environment.' We deem it expedient to present in the EIAR which forecasts substantiate this statement, with particular regard, from a river basin management perspective, to cases such as the receiving water body warming up due to external conditions (weather) and the higher temperature of the discharged cooling water exactly for the above reasons, or regarding the decline in low water levels.		in the event of a Danube water temperature of 40°C; thus, the values featured in the forecasts do not materially endanger nuclear safety. The measures defined in relation to the decline in low water levels also provide an adequate margin for water abstraction. From a river basin management perspective, the assessment of the impacts of changing external conditions is presented in *Annex 3*.
The analysis presented within the subsection ('Trends in the flow rate and water level of the Danube upstream of Paks') of Section 5.2.2 of the preliminary consultation document was prepared on the basis of data predating 2013. The associated Figure 5.2.2-3 presents the logarithmic smoothing of variations in annual low, mean, and high-water levels at the 1531.3 river-kilometre cross-section of the Danube. This figure likewise presents the variations only up to 2013. We deem it expedient to update the analysis at least up to the point in time corresponding to the reference date (31 December 2023), and to take into account accordingly the changes occurring in the period elapsed since then, along with the trends determined based thereon, and to determine on this basis, in particular, the expected evolution of low water levels.	*Chapter 4.3.* *Annex 3.*	The assessments conducted on the basis of the updated data are contained in *Annex 3* and *Chapter 4.3.*, respectively. The time series analyses have been supplemented up to and including year 2023. Trend analyses on historical data were performed, while the evolution of expected low water levels was determined using physically-based hydrological modelling built upon the outputs of climate models.
Changes that have occurred over time and observed trends (e.g. the deepening of the Danube riverbed) must also be taken into account regarding hydro-morphological characteristics and analyses.	*Chapter 4.3.* *Annex 3.*	The relevant analyses are contained in *Annex 3* and *Chapter 4.3.*, respectively. The trend analysis of historical data has been performed, while future projections were prepared on the basis of a 1D hydro-morphodynamic model that also accounts for changing discharge forecasts in the light of climate change.
In order to present the expected evolution of the Danube water levels, which fundamentally dictate the operating conditions of	*Chapter 4.3.* *Annex 3.*	The relevant analyses are contained in *Annex 3* and *Chapter 4.3.*, respectively.

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
the power plant, it is deemed appropriate to examine and present the following: − A comparison of the linear trend of water level time series against the logarithmic approximation; − Demonstrable empirical correlations between water level, discharge, and riverbed morphology characteristics; − Whether changes in bed degradation processes are anticipated based on the analysis results of bed material and sub-riverbed soil strata; − The potential impact of the nearest erosion thresholds upstream of the power plant cross-section on low water levels, taking riverbed degradation into account.		A logarithmic regression analysis of the discharges has been performed, quantifying the rate of relative discharge reduction. The stage-discharge curves determined for the low-to-mean flow range were presented for 10-year time windows, on the basis of which the extent of riverbed degradation was quantified.
The Environmental Impact Assessment Report must present the variation in the impact of the cooling water discharge in detail and supported by data, with particular regard to the rising temperatures of the Danube mentioned in the assessment, the future projections, and must also account for the changes following the commissioning of the Paks II NPP. This is required because the service life extension also significantly increases the duration of the two power plants' concurrent operation compared to what was previously planned, meaning that this impact will be imposed over a much longer period. The analyses must give due consideration to low water and extremely warm periods, as well as to the thermal differential developing during winter operations.	*Chapter 4.3.* *Annex 3.*	The assessment of the thermal load on the Danube is contained in *Annex 3*, and the results of the assessment are summarised in *Chapter 4.3*. *Annex 3* discusses the environmental impacts of the individual operating conditions (scenarios) in detail, the climatic and hydrological baselines of which are provided by climate models extending up to 2060, and the hydrological models developed on this basis. The impact assessment was prepared using a conservative approach across all operating conditions with respect to critical conditions; that is to say, it presents the maximum calculable impact. Based on ecological analyses, the winter thermal differential does not represent such a critical condition.
The variations in the pollutant load resulting from wastewater discharge (concentrations and annual loads of discharged substances) must be presented in detail and quantified, addressing also the impact of concurrent operation with Paks II	*Chapter 4.3.* *Annex 3.* *Annex 4.*	The assessment of the impacts of wastewater discharge is contained in *Annexes 3* and *4,* and *Chapter 4.3.* *Chapter 4.3.* presents the water quality and ecological impacts of the discharge of treated wastewater into the Danube, as well as the discharge of untreated wastewater as an emergency event, across all scenarios in a manner supported by data and calculations.
In Chapter 5.3.4 ('Impacts of Emergency Events') of the preliminary consultation document, it would be advisable to	*Chapter 2.3.3.*	The emergency events investigated in the EIAR are outlined in *Chapter 2.3.3*.

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
present the specific hypothetical incidents investigated to arrive at the conclusions of the chapter.		The principle for selecting the emergency scenarios to be investigated in the EIAR was that the chosen event must envelope the environmental impacts of all other potential emergency cases.
In *Chapter 5.5.2*. ('Expected impacts During SSLE') of the preliminary consultation document, the impact ratings presented in the tables for both the independent operation of the Paks NPP and the concurrent operation of the two power plants indicated a neutral impact regarding macrozoobenthos and fish. However, according to earlier sections in the document provided to us, there are detectable impacts within the impact area, and they point to a condition worse than neutral: − Macrozoobenthos – Presence of non-native elements, a significant proportion of which are invasive and aggressively expanding, detectable within 2 km (Chapter 5.3 - Page 130) − Fish – the warm water discharge from the NPP causes a detectable change in the community structure indices of fish up to a value of $\Delta t_{\_water}$ = 2.5°C. According to previous studies, the warm water discharge also represents a perceptible change at the species level. As an indirect impact of the warm water discharge, the nearby downstream section (primarily areas characterised by slower flow and shallower water associated with backwaters) may emerge as emission hotspots for several invasive, primarily pioneer fish species. (Page 130 in Chapter 5.3.) It appears advisable to clarify, reconcile, and explain the contradictory data.	*Annex 3.* *Annex 6.*	The analysis of impacts on the aquatic life and its evaluation are contained in *Annex 3*. The Paks NPP on aquatic organisms are presented in detail in *Annex 3*. In the EIAR, the aforementioned contradictions have been corrected by amending the contents of the ecology and nature conservation chapter (*Annex 6*).
In Chapter 8, it is recommended to finalise the delineation of the impact areas and the summary tables in accordance with the revisions carried out on the basis of the comments. The tables presenting the impact areas should also be supplemented with data characterising the concurrent operation in the EIAR.	*Chapter 7.* Discipline-specific annexes	The delineation of the impact areas for the individual environmental receptors is contained in the discipline-specific annexes, while the aggregated impact areas are presented in *Chapter 7*. For those environmental impacts where the effects or impact areas of the Paks NPP can be determined cumulatively with the environmental impacts of Paks II NPP (e.g. the thermal load of the Danube, noise emissions), the impact areas have been presented accordingly.

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
On the basis of the contents of the preliminary consultation document, due to the upwelling hydrodynamic regime characteristic of the power plant's immediate impact areas – which geographically correspond to the Danube Valley – the impact of any potential surface pollution on the hydrochemical parameters of groundwater abstractions can be considered negligible. At the same time, the cones of depression generated by groundwater abstractions are highly likely to modify this upwelling regime; consequently, pressure potentials that decrease with depth – and therefore local downwelling zones – may develop within their impact areas, which could increase the risk of surface pollution migrating into the groundwater.	*Annex 4.* *Annex 5.*	The pressure potentials and their variations are presented in *Annexes 4* and *5*. Within the framework of the SSLE analysis of the Paks NPP, the Csámpa-puszta catchment area was affected by assessment. For this purpose, the report "Review document on the Paks – Csámpa drinking water source protection zone and the overlying protective area", which addresses the designation and safeguarding of the drinking water resource protection zone, was also used. The documentation states that the highest point (closest to the surface) of the protection area, which can be defined by the streamlines corresponding to a 50-year travel time within Hydrogeological Zone 'B', was identified to be at a depth of 80 m below ground level (17 mBSl). During the preparation of the SSLE EIAR, a 2.5-fold increase in discharge was assumed for the operation of the Paks NPP and Paks II NPP; its impact also failed to reach the surface, affecting only the 6th model layer (Pannonian silty-clayey sand), the top of which is located at a depth of 73 metres below ground level (24 mBSl). It is therefore proven that the cone of depression developing around the wells of the water resource area does not reach the surface; that is to say, the layers containing drinking water are not endangered by surface contamination. The shallow contamination occurring at the Paks NPP site is presented in detail in *Annex 4*. Contamination from the site cannot reach the wells of the Csámpa-puszta water resource area because the impact of the increased abstraction also affected only the Pannonian silty-clayey layer, which has no surface outcrop; furthermore, the recharge area does not face towards the Paks NPP site but quite the opposite, as groundwater flows towards the wells of the water resource area from a west-north-westerly direction. Generally speaking, operating water resource areas have statutorily designated protection zones, and by complying with their regulations, variations in water quality can be detected in due time.

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
It is recommended to consider during the detailed environmental impact assessment how the microbiological and hydrological changes that may potentially develop as a result of thermal load in the foreland of prospective and operational bank-filtered water resource areas affected by the thermal plume (under both current operations and concurrent operation with Paks II) could influence the lithology and hydrodynamic parameters of the clogged riverbed sediments, thereby affecting the operational mechanism and efficiency of bank filtration.	*Annex 5.*	The impacts of thermal loading on the water resource areas are described in *Annex 5.* The assessment of the impacts of the Paks NPP and Paks II NPP on the clogged zone is detailed in *Chapter 6.4.* of *Annex 5.* In summary, an increase in the extent of colmatage itself – and the associated reduction in hydraulic connectivity between surface water and groundwater – further mitigates the impacts of the Paks NPP, and in the future, the concurrent impacts of the Paks NPP and Paks II NPP, on groundwater bodies; which is favourable from this perspective but it would have an adverse effect on the installation and operation of bank filtration systems. Cross-section 2 of Paks NPP's bank filtration monitoring system confirms that the purification effect of the colmatage zone remains demonstrably active at present. The magnitude of the impact on the colmatage zone is acceptable and requires no remedial intervention.
4. Central Transdanubian Water Directorate (KDTVIZIG)		
According to the opinion of the KDTVIZIG, the preliminary consultation documentation regarding the SSLE of Paks NPP's Units 1-4 does not prejudice any water management interests, and the authority accepts the contents therein.	–	It does not set forth any task to be performed in the EIAR.
It was noted in the opinion that the manager of the main Danube riverbed is the Lower Danube Valley Water Directorate (ADUVIZIG); they handle issues concerning the Danube riverbed in greater detail and provide the statutory opinion on the impacts of the NPP on the river.	–	It does not set forth any task to be performed in the EIAR.
5. South Transdanubian Water Directorate (DDVIZIG)		
DDVIZIG has reviewed the document of 'The preliminary consultation on the SSLE of Paks NPP's Units 1-4, operated by MVM Paksi Atomerőmű Zrt.' and has made recommendation or observation in relation therewith.	–	It does not set forth any task to be performed in the EIAR.

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
6. Danube-Drava National Park Directorate		
From nature conservation perspective, no disqualifying factors have arisen in relation to the SSLE.	–	It does not set forth any task to be performed in the EIAR.
From a nature conservation perspective, the Environmental Impact Assessment Report to be submitted as an appendix to the environmental permit must investigate the following:		
− The impacts of the Paks NPP's operation on the conservation status of the Dunaszentgyörgy fen wood nature reserve and Natura 2000 site, with particular regard to its ongoing water supply, ensuring the ecological water requirements of protected and qualifying species and habitats, assessing the feasibility of providing emergency supplementary water, and evaluating the impacts of variations in discharge, water quality, and water temperature developing within the thermal discharge channel on the flora and fauna in the area.	*Annex 6.*	The assessment of impacts on the aquatic life is contained in *Annex 3.* The impact assessment of the Natura 2000 site affected is contained in the attachment to *Annex 6*. Based on the consultations between MVM Paksi Atomerőmű Zrt. and the Duna-Dráva National Park Directorate on this matter, winter water abstraction for the purpose of flooding the fen wood is feasible, provided that the summer water levels of the Fadd Danube backwater can still be maintained, and it is clarified what other conditions outside the competence of MVM Paksi Atomerőmű Zrt. are necessary for the implementation.
− The impacts of the cooling water from the Paks NPP, and its quantitative, qualitative, and thermal variations, on the receiving water bodies and their flora and fauna.	*Chapter 4.3.* *Annex 3.*	The assessment of impacts on water bodies and the aquatic life is contained in *Annex 3*. *Annex 3* contains impact assessments for all scenarios on the basis of climate and hydrological models prepared for the entire duration of the SSLE, using data-driven statistical evaluations of archive data from biological analyses conducted between 2002 and 2023, as well as data from recent surveys carried out in 2024 and 2025.
− Assessment of the potential impacts of light pollution caused by the lighting at the Paks NPP, with particular regard to the bat and insect fauna, as well as nocturnal migratory bird species.	*Chapter 4.5.* *Annex 6.*	The assessment of the impacts of light pollution is contained in *Annex 6,* and *Chapter 4.5.* According to the findings of the analyses conducted as part of the EIAR, perceptible, adverse impacts can also be established in respect of the lighting of the site as an impact factor. However, based on the categorisation under the applied impact evaluation system, the magnitude of the impact for this factor is merely minor and tolerable.

Opinion from other body	EIAR chapter containing fulfilment of task	Summary of the fulfilment of the task or requirement
A significant transboundary effect of the proposed service life extension on nature conservation interests can only be assumed in the event of an accident.	*Chapter 8.*	The examination of transboundary effects is included in *Chapter 8*. No transboundary effects on the natural environment are anticipated, even in the event of an accident. According to the radiological protection analyses conducted for serious accidents, any effects impacting the transboundary population – and consequently the natural environment – do not deviate significantly from the global average annual natural background radiation value of 2.4 mSv, even under the worst-case scenario.
7. Kiskunság National Park Directorate (KNPI)		
Based on the submitted documentation and the data available to us, the further operation of the power plant will not cause any additional adverse impact from a landscape and nature conservation perspective within the jurisdiction of the KNPI; our Directorate submits no observations in relation to the contents of the preliminary consultation documentation.	–	It does not set forth any task to be performed in the EIAR.

1.3. Definition, purpose and justification of the planned activity

1.3.1. Identification, volume, commencement date and duration of the planned activity, and consideration of alternatives

The planned activity is the subsequent 20-year extension of the service life – and thus the power generation activity – of Paks NPP, which operates with four VVER-440/213 type pressurized water, light-water moderated, thermal reactor units. The SSLE of the plant falls under Point 31 of Annex 1 of Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures ("*Nuclear power plant, nuclear reactor, as well as the service life extension of a nuclear power plant or nuclear reactor*" – without size limitations). Therefore, it qualifies as an activity subject to a mandatory environmental impact assessment, the commencement of which requires an environmental license. The planned activity also includes the activities and alterations planned to be executed as part of the preparations for the SSLE, as presented in *Chapter 2.2.2*.

The proposed SSLE applies to all four units of the NPP and is to be understood on a unit-by-unit basis, considering the commissioning dates of each individual unit. The planned commencement date of the activity corresponds to the expiry of the validity – defined on a unit-by-unit basis – of the currently effective and repeatedly amended environmental license with reference number 391-18/2017, as shown in *Table 1.3.1-1.* According to the intention of MVM Paksi Atomerőmű Zrt., the duration of the SSLE for each unit shall last until the end of the final year of the extended service life of the given unit (*Table 1.3.1-1*).

The nominal electrical capacity of Units 1-4 of Paks NPP is 508.6, 506.0, 506.0 and 506.0 MW, respectively, while the total aggregated nominal electrical capacity of the facility is 2,026.6 MW. With the implementation of the subsequent 20-year service life extension, the planned temporal distribution of the NPP's available power generation capacity utilisation will develop as shown in *Table 1.3.1-2*. During the SSLE period, the power plant is planned to continue operating as a base-load station with continuous and near-uniform loading; the shutdown of the units will occur only in a planned and scheduled manner during periodic maintenance.

Table 1.3.1-1. Proposed duration of the SSLE

Power plant unit/ system	Date of commissioning	End of the 50-year service life/ commencement of the subsequent 20-year service life extension	End of the proposed subsequent 20-year service life extension
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.
Shared systems		09.08.2037.	31.12.2057.

Table 1.3.1-2. The planned temporal distribution of the NPP's capacity utilisation during the SSLE period

Time	The total electrical output of the NPP [MW]	Operating units
14.12.2032. – 31.12.2052.	2 026.6	1-4.
01.01.2053. – 31.12.2054.	1 518.0	2-4. (Unit 1 shut down)
01.01.2055. – 31.12.2056.	1 012.0	3-4. (Units 1-2 shut down)
01.01.2057. – 31.12.2057.	506.0	4. (Units 1-3 shut down)

Among the activities and reconstruction planned in preparation for the SSLE, an activity involving significant construction work is the implementation of the alternative warm-water channel section and peak cooling system, the purpose of which is to reduce the temperature of the Danube water used for cooling purposes in the NPP, which has thus warmed up, before being returned to the river. The implementation of the alternative warm-water channel section and the peak cooling system requires the construction of an approximately 950 m long reinforced concrete-lined channel, hydraulic structures, artificial draft cooling cells, and the related solid-surfaced road and underground cable. The placement of these artificial elements is planned in the area south of the existing warm-water channel of the NPP, mainly in the construction zone of the industrial economic area designated Gip-M/PI – i.e. in the area intended for construction. The total area occupied by the structures is nearly 10 ha.

Considering the construction zone classification of the implementation area (intended for construction) and the area requirements of the structures and artificial elements to be installed, the construction of the planned alternative warm-water channel section and the peak cooling system falls under point 128 of Annex 3 to Government Decree 314/2005. (XII. 25.) (*"other structures or groups of structures not included in points 1-127/A. in built-up or intended-for-construction areas, from 2 ha of area occupation"*), i.e., depending on the decision of the environmental protection authority, it is an activity subject to an environmental impact assessment. However, since the alternative warm-water channel section and the peak cooling system are part of the SSLE preparatory activities, the EIA carried out, and the prepared EIAR – in accordance with the content requirements specified in Government Decree 314/2005. (XII. 25.) regarding the impact assessment – also included the assessment of the environmental impacts resulting from the construction and operation of these facilities. The scope and depth of the investigations carried out thus correspond to the detail of the EIA in accordance with the requirements for the content of the EIAR in Annex 6 of Government Decree 314/2005. (XII. 25.).

The environmental impact assessment of the NPP concerning the SSLE as a planned activity covers all four units of the plant, including the preparatory activities scheduled for the implementation of the SSLE. Accordingly, the assessments presented in this EIAR have been conducted for the four-unit operation of the NPP.

The location of the activity is Hungary, Tolna County, administrative area of the town of Paks (7030 Paks, topographical number: 8803/17), the existing site of the Paks NPP.

The sole option considered is the SSLE of the existing NPP at the current site and with the existing technological process, including the planned modifications required for this, presented in *Chapter 2.2.2.* No other siting, technological, or alternative options exist in this case. Apart from implementing the SSLE of the NPP, decommissioning of the plant's units without SSLE and the cessation of its electricity generation activity at the end of the currently authorised 50-year operating lifetime can be interpreted as the only alternative as per the legislation. Information regarding the decommissioning of the NPP is contained in *Chapter 6*.

1.3.2. Purpose and justification of the planned activity

The purpose of the planned activity is to maintain the commercial electricity generation currently carried out by MVM Paksi 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 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 National Energy and Climate Plan (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 NPP 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 NPP 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 NPP 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 NPP 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 NPP 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 BME, 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 SSLEof 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. Description and identification data of the applicant and data of the authors of the EIAR

1.4.1. Identification data of the MVM Paksi Atomerőmű Zrt.

The applicant for the environmental license is MVM Paksi Atomerőmű Zrt., its identification data 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 offices:	H-7030 Paks, Topographical lot number: 8803/17.
Postal address:	H-7031 Paks, P.O. Box. 71.
E-mail address:	atomeromu@npp.hu
Website:	atomeromu.mvm.hu
Central phone number:	+36 (75) 505-000
Company registration number:	17-10-001113
Tax ID:	10742833-2-17
Core activity:	3511 electricity generation
Environmental Client Identifier (KÜJ):	100 203 714
Environmental Site Identifier (KTJ):	100 294 388
Statistical code:	10742833-3511-114-17
Number of the environmental permit for the current electricity generation activity:	391-18/2017 (amended several times between 2018 and 2024)

For its electricity generation activity, MVM Paksi Atomerőmű Zrt. has been operating an environmental management system certified under the MSZ EN ISO 14001:2015 standard since 2002. The compliance of the system's operation is verified by annual review audits and triennial recertification audits. The scope of the environmental management system covers all operational processes, every employee, organisational unit, and any other person in a working relationship, as well as contractual partners and their employees.

1.4.2. Data of the authors of the EIAR

The specific technical sections of the EIAR were prepared by the professional organisations involved in the environmental impact assessment, with the cooperation and technical coordination of the engineering consultancies MVM ERBE Zrt. (H-1117 Budapest, Budafoki út 95.), AFRY SOM System Kft. (H-1117 Budapest, Infopark sétány 3.), and AFRY ERŐTERV Zrt. (H-1117 Budapest, Infopark sétány 3.).

The EIAR was compiled by AFRY ERŐTERV Zrt. The professional organisations cooperating in the preparation of the documentation and their respective technical disciplines were as follows:

- MVM ERBE Energetika Mérnökiroda Zrt.:
  - Project management.
  - Technical direction of non-radiological (conventional) analyses.
  - Air quality control.
  - Noise and vibration control.
  - Ecological protection assessment.
  - Technical coordination of tasks related to the compilation of the EIAR.
- AFRY SOM System Mérnöki Iroda Kft.:
  - Technical direction of radiological analyses.
  - Site characterisation.
  - Technical coordination of tasks related to the compilation of the EIAR.
- AFRY ERŐTERV Energetikai Tervező és Vállalkozó Zrt.:
  - Power plant technology.
  - Technical coordination of tasks related to the compilation of the EIAR.
  - Compilation of the EIAR.
- HUN-REN Csillagászati és Földtudományi Kutatóközpont (HUN-REN CSFK):
  - Site characterisation (geography, meteorology, socio-economic assessments).
- GeoRisk Földrengés Mérnöki Iroda Kft.:
  - Site characterisation (geology, seismology-tectonics, geotechnics).
- NUBIKI Nukleáris Biztonsági Kutatóintézet Kft.:
  - Site characterisation (assessment of external hazards).
- Nemzeti Népegészségügyi és Gyógyszerészeti Központ (NNGYK), Közegészségügyi Laboratóriumi és Módszertani Főosztály:
  - Air quality control
- NATURAQUA Környezetvédelmi, Tervező és Szolgáltató Zrt.:
  - Protection of surface and groundwater.
  - Geological medium protection.
  - Non-radioactive waste treatment.
- SCIAP Kutatás-fejlesztési és Tanácsadó Kft.:
  - Protection of surface waters and aquatic life.
- Budapesti Műszaki és Gazdaságtudományi Egyetem Vízépítési és Vízgazdálkodási Tanszék (BME VVT).
  - Protection of surface waters.
- Kék Csermely Vízvédelmi és Környezetgazdálkodási Tervező és Szervező Kft.:
  - Protection of surface and groundwater.

- Isotoptech Nukleáris és Technológiai Szolgáltató Zrt.:
  - Analysis of the radiation exposure of biota.
  - Protection of groundwater.
- HUN-REN Energiatudományi Kutatóközpont (HUN-REN EK), Atomenergia-kutató Intézet::
  - Radiation protection, analysis of the radiation exposure of the population.
- SOMOS Környezetvédelmi Fejlesztő Szolgáltató és Kereskedelmi Kft.:
  - Analysis of environmental radioactivity.
- BioAqua Környezetvédelmi, Szolgáltató és Tanácsadó Kft.:
  - Wildlife and nature conservation.
- ÖKO Környezeti, Gazdasági, Technológiai, Kereskedelmi, Szolgáltató és Fejlesztési Zrt.:
  - Municipal environment ,landscape protection.
- V-MED Oktatási, Kutatási és Szolgáltató Bt.:
  - Analysis of the health status of the population.

The list of the individual technical experts and the verification of their professional certifications – in alignment with the current data from the official public register of the Hungarian Chamber of Engineers[1] and the Register of Nature Conservation and Landscape Protection Experts of the Ministry of Agriculture[2] – are contained in *Table 1.4.2-1*.

Table 1.4.2-1. Experts contributing to the preparation of the EIAR and their professional certifications

Organisation	Expert / Technical discipline(s)	Chamber registration number(s) / certification and licence codes, access to the expert register entries
AFRY ERŐTERV ZRt.	Rozália Gátiné Magyar Radiation protection	01-15651, 01-64695 EN-A, NSZ-3., NSZ-11., NSZ-17., NSZ-19. SVR-HA18098 https://www.mmk.hu/nevjegyzek?id=1961
AFRY ERŐTERV ZRt.	Péter Hayer Waste management, air quality protection, protection of water and geological medium, noise and vibration control	01-2861 SZÉM5, SZÉM6, EN-HŐ, EN-ME, EN-VI, SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4. https://www.mmk.hu/nevjegyzek?id=52880
AFRY ERŐTERV ZRt.	Tamás Romenda Waste management, air quality protection, protection of water and geological medium, noise and vibration control, climate protection	01-12548, 01-64686 SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4., K-Sz, NSZ-3., NSZ-11., NSZ-17., NSZ-19., NSZ-20. SVR-HA19197 https://www.mmk.hu/nevjegyzek?id=2056
BioAqua Pro Kft.	Dr. Béla Kiss Hydrobiology, ecology	SZ-050/2011., SZ-018/2018. SZTV, SZTjV https://ttsz.am.gov.hu/szakertok/338
MVM ERBE Zrt.	Dr. Zsófia Fehér Noise and vibration control, protection of flora and fauna	13-11655, Sz-001/2010., SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4., SZTV, SZTjV https://www.mmk.hu/nevjegyzek?id=12495 https://ttsz.am.gov.hu/szakertok/82

[1] ttsz.am.gov.hu/szakertok/szemelyek
[2] www.mmk.hu/informaciok/nevjegyzek

Organisation	Expert / Technical discipline(s)	Chamber registration number(s) / certification and licence codes, access to the expert register entries
MVM ERBE Zrt.	Emőke Nagyné Juhász Protection of water and geological medium	01-11964, 01-66916 SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4., SZVV-3.1., SZVV-3.9., SZVV-3.10., VZ-TEL, VZ-TER, ME-VZ, MV-VZ, VZ-VKG https://www.mmk.hu/nevjegyzek?id=51823
MVM ERBE Zrt.	Dávid Pintér Air quality protection, climate protection	07-01251 SZKV-1.1., SZKV-1.2., SZKV-1.3., K-Sz https://www.mmk.hu/nevjegyzek?id=37132
NATURAQUA Zrt.	Tamás Kerékgyártó Protection of water and geological medium, climate protection	05-01890 SZKV-1.3., SZVV-3.1., SZVV-3.5., SZVV-3.9., SZVV-3.10., K-Sz https://www.mmk.hu/nevjegyzek?id=68324
Kék Csermely Kft.	György Maján Protection of water and geological medium	01-3036 SZKV 1.1., SZKV-1.3., VZ-TEL, VZ-TER, ME-VZ, MV-VZ, VZ-VKG https://www.mmk.hu/nevjegyzek?id=30131
ÖKO Zrt.	Emőke Magyar Landscape protection, municipal environment	SZ-033/2009. SZTV, SZTjV https://ttsz.am.gov.hu/szakertok/186
AFRY SOM System Kft.	Anita Puskás Nuclear environment protection, radioactive waste management	17-06000 NSZ-19., NSZ-20. https://www.mmk.hu/nevjegyzek?id=84969
SOMOS Kft.	Dr. Gábor Nagy Radiation protection	13-15382, 13-66064 NSZ-10.2., NSZ-11. SVR-HA16235 https://www.mmk.hu/nevjegyzek?id=61318
V-MED Bt.	Prof. Dr. János Sándor Human health	Specialist Medical Certificate in Public Health and Epidemiology as well as in Preventive Medicine and Public Health

1.5. The environmental impact assessment procedure and its relationship with other permitting procedures, specific characteristics of the impact assessment for the planned activity

1.5.1. Legislative background of the environmental impact assessment and other regulatory permitting procedures

Pursuant to Section 68 of Act LIII of 1995 on the general rules of environmental protection, before commencing activities that have or are anticipated to have a significant impact on the environment, an environmental impact assessment must be conducted, and an environmental license must be obtained from the competent environmental authority. Government Decree 314/2005. (XII. 25.), sets forth the scope of these activities, furthermore the method and phases of the environmental permitting procedure, as well as the content requirements for the documents to be submitted to the environmental authority. According to the Government Decree, EIA apply not only to new facilities but also to alterations and modifications in existing ones as specified in the decree; thereby, including the service life extension of the NPP.

In the case of activities subject to a mandatory EIA, pursuant to Section 67 of Act LIII of 1995, the operator (applicant) may initiate a preliminary consultation with the environmental authority.

Under Section 5/A (2) of Government Decree 314/2005. (XII. 25), the purpose of the preliminary consultation is to enable the operator to receive a written opinion from the environmental authority regarding the content requirements of the EIAR, covering environmental and nature conservation issues as well as other specific technical matters specified in Annex 12 of the Government Decree. Furthermore, the purpose of the preliminary consultation is to enable the public (through the publication of the documents) to express their observations regarding the planned activity.

Following the preliminary consultation, the EIA procedure is initiated by the environmental authority upon the application of the operator. The application must be accompanied by the EIAR that is compliant with the opinion issued by the authority during the preliminary consultation and with the general content requirements under Annex 6 of Government Decree 314/2005. (XII. 25).

The operation of NPPs is an activity falling under the scope of (Appendix I to) the Convention on Environmental Impact Assessment in a Transboundary Context, signed in Espoo (Finland) on 26th February 1991 and promulgated by Government Decree 148/1999. (X. 13.), which is presumed to potentially have a significant transboundary environmental impact. If a significant transboundary environmental impact can be assumed in connection with the activity assessed during the preliminary consultation, the Ministry responsible for environmental affairs shall notify the foreign affected parties of the planned activity, and of the EIA procedure currently underway in relation thereto. Should the foreign affected party declare in its response to the notification that it wishes to participate in the EIA procedure, the procedure must then be pursued taking into account the provisions of the Espoo Convention (international EIA procedure). During this process, the EIAR and the associated documentation shall be forwarded to the affected parties, and consultations shall be conducted with the foreign affected parties concerned, in order to inform them and to learn their opinions thereon. The environmental authority shall take into account the opinions and observations received from the foreign affected parties during the international procedure when making its decision regarding the environmental license.

Following the environmental licensing procedure, nuclear safety and electricity industry licensing procedures shall also be conducted for the SSLE of the NPP.

Pursuant to the provisions of Section 17 (2) 1 b) of Act CXVI of 1996 on atomic energy, the competence of the nuclear regulatory body, namely the Hungarian Atomic Energy Authority (HAEA), encompasses the nuclear safety licensing required for the construction, expansion, commissioning, operation, and operation beyond the nuclear facility's design lifetime, as well as for its service life extension subsequent to the operation beyond the design lifetime, which forms the subject of the present assessment, and for its decommissioning. Pursuant to Section 18(1)(e) of OAH Decree 1/2022. (IV. 29.) on the nuclear safety requirements for nuclear facilities and the related regulatory activities, an operating license issued by the nuclear safety authority, the HAEA, is required not only for the operation and operation beyond the design lifetime of a nuclear facility, but also for its further service life extension (SSLE) to the operation beyond the design lifetime. Obtaining the final environmental license is a prerequisite for issuing the nuclear safety (operating) license relating to the SSLE.

The licensee shall notify the nuclear safety authority of its intention to further operate the NPP units subsequent to the operation beyond their design lifetime, at the latest four years prior to the expiry of the valid operating license, and shall simultaneously submit its implementation program envisaged for establishing the conditions for the service life extension subsequent to the operation beyond the design lifetime. The HAEA shall approve the implementation program, provided that it complies with the requirements set out in the HAEA Decree, and shall supervise its execution. The licenses necessary for carrying out modifications arising during the fulfilment of the SSLE implementation program must be obtained separately during the term of the valid operating license, in accordance with the rules governing the licensing of the relevant activity.

The HAEA will authorise the service life extension subsequent to the operation beyond the design lifetime in a new operating license issued upon the application of the licensee. The application for the license must be submitted per NPP unit, at the latest one year prior to the expiry of the valid operating license. The detailed rules of licensing are contained in Volumes 1 and 4 of the Nuclear Safety Code, which form the annexes to OAH Decree 1/2022. (IV. 29).

Pursuant to Section 74 (1) b) of Act LXXXVI of 2007 on electricity, the electricity generation by a power plant with a nominal capacity of 50 MW or more may be conducted in possession of an electricity generation operating license issued by the Energy and Public Utility Regulatory Authority (MEKH). Pursuant to Section 75 (4) of the Act, the rules governing the granting of a license shall apply to the extension of an operating license. In the case of a NPP, the temporal validity of a generation operating license may be extended at the earliest five years prior to the expiry of the license. The application for the extension of the temporal validity of a generation operating license must be submitted at the latest 180 days prior to the expiry of the license. The detailed rules of the licensing are set forth by Government Decree 273/2007. (X. 19.) on the implementation of certain provisions of Act LXXXVI of 2007 on electricity.

Figure 1.5.1-1. provides an overview of the entire licensing process and its legislative background.

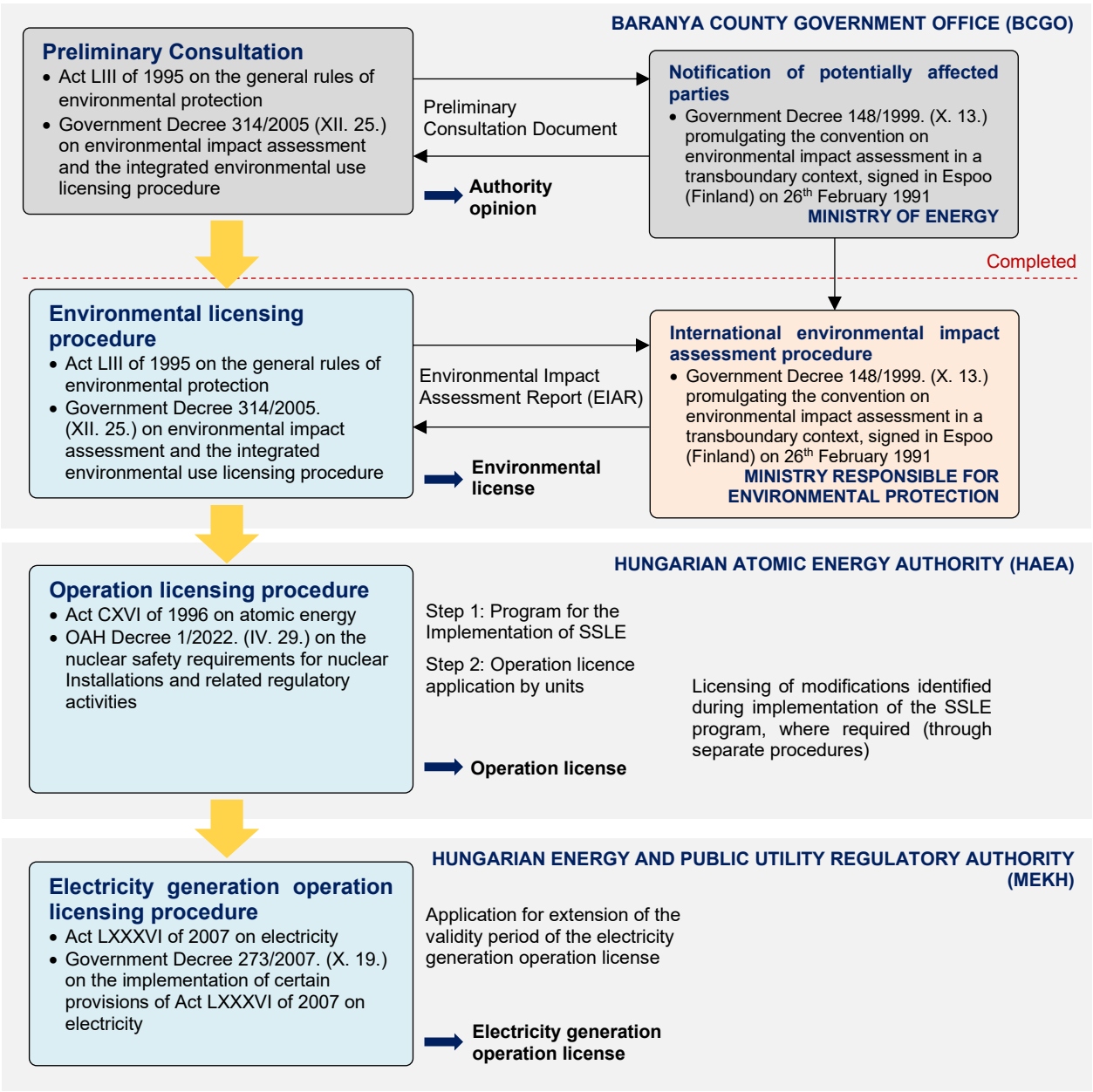


Figure 1.5.1-1. Licensing process for the NPP SSLE

1.5.2. Specificities of the EIA for the planned activity

The environmental impact assessment for the SSLE of the Paks NPP can be considered unique in several respects compared to a conventional impact assessment relating, typically, to a new activity. In light of the legislative requirements governing the impact assessment, these specific characteristics are as follows:

- From an impact assessment perspective, the most significant specificity of the planned activity is that the procedure relates to a facility that has already been operational for decades. In general, environmental audits are applied to survey and evaluate the environmental impacts caused by an ongoing activity. However, the service life extension of a NPP is an activity subject to a mandatory environmental impact assessment.
  Consequently, in this case, the completion of an environmental impact assessment procedure is required, as opposed to an environmental audit procedure, even if this concerns the further continuation of an existing activity, where forecasts regarding the

anticipated environmental impacts can be based largely on actual measurements and empirical results rather than on estimation.

- Government Decree 314/2005. (XII. 25.) does not define a separate, independent system of requirements for conducting an impact assessment related to the modification of existing facilities. However, the content requirements for impact assessments developed for new facilities are not applicable in all respects to the modification of operational plants. For a new activity, a question of paramount importance in the EIAR is whether the planned activity and its associated facilities can be integrated into the given environment. The content requirements of the legislation also concentrate on this aspect. In the present case, this can only be an issue regarding the modifications planned as preparation for the SSLE (e.g., the implementation of the alternative warm-water channel section and the associated peak cooling system /*Chapter 2.2.2./*), as electricity generation as an activity has already been integrated into the environment, and the NPP has been operational since 1982. Since the current environmental impacts and impact pathways associated with the power plant are expected to remain definitive in the future, the acceptability of the plant's current environmental impacts is a material aspect for the assessment of the future activity as well. Therefore, the focus of both the preliminary consultation documentation (PCD) prepared for the preliminary consultation and the EIAR is on the presentation of the current status, and the current environmental impacts are also evaluated and qualified. (In order to present the current status as comprehensively as possible, an environmental baseline assessment monitoring program was also executed as part of developing the PCD and the EIAR to substantiate the EIA.)

  In the present case, the environmental impact assessment must focus on whether the current status is acceptable, and on how the cumulative environmental impacts of the power plant’s subsequent service life will change due to the anticipated 20-year service life increment. Furthermore, the expected changes in environmental characteristics must also be taken into account (e.g. climate change, predictable changes in the hydrological characteristics of the River Danube, population, and human activities carried out in the environment).
- It is also a specificity that, since the subject of the assessment was a NPP in the present case, it was necessary to account not only for conventional environmental discharges but for radiological discharges as well. With respect to every environmental element and system, both analytical approaches were applied. (Environmental impacts and specialist areas not related to radioactivity or radiation protection are hereinafter referred to as “conventional” in the document.) A further material circumstance related thereto is that the concepts and definitions applied correspond to the established practice of each respective specialist area. An example is that the concept of an emergency used in the conventional specialist area corresponds to the concepts of operational incident and accident in the case of specialist areas related to radioactivity or radiation protection as applied in the Nuclear Safety Code.
- In the case of existing facilities, environmental impact factors and impact pathways, as well as the resulting status changes, can be characterised by the results of monitoring activities conducted during the operation to date, and estimated for the period of the SSLE. The current status of environmental elements and systems fundamentally predetermines the environmental status anticipated during further operation as well. The reason for this is that the proposed service life extension does not require the alteration or modification of the NPP’s electricity generation technology, nor does it necessitate significant reconstruction within the operational plant. The activities substantiating the execution of the SSLE fundamentally comprise the review, inspection, and preservation of existing plant buildings, structures, facilities, and equipment, as well as the replacement and refurbishment of ageing equipment and components (activities which also form part of the works fundamentally necessary for the normal operation of the NPP; i.e. authorised until 2032-2037). However, within the framework of preparing for the implementation of the SSLE, a number of modifications are also planned (*Chapter 2.2.2.*), the potential

environmental impacts of which have also been assessed as part of substantiating the EIAR.

- The installation phase to be examined in conventional environmental impact assessments (defined by the legislation as “establishing the conditions necessary for exercising the activity, in particular land acquisition, site preparation, construction, and installation of equipment”) can only be partially interpreted in the present case. The implementation of modifications planned as preparation for the SSLE (primarily the implementation of the alternative warm-water channel section and the associated peak cooling system), along with other activities related to the modernisation, reconstruction, and replacement of individual equipment, may be taken into account as the installation phase. However, a significant portion of those activities is continuous even during normal operational functioning; therefore, an independent assessment of this phase is required only with respect to significant incremental environmental impacts that arise as an addition compared to normal operation. Conversely, the impacts arising from activities carried out continuously during operation have already been addressed, evaluated, and authorised as part of the EIAR for the service first life extension (as the continued operation of the NPP).
  As part of the installation phase, namely the preparation phase for the Paks NPP’s SSLE, it was necessary to evaluate within the present impact assessment those interventions that from an environmental perspective go beyond normal operational upkeep and maintenance works, are of a larger volume or higher frequency, or possibly require a campaign period, and consequently entail incremental environmental impacts. These activities were defined as a result of the detailed technical condition and integrity assessment analyses conducted in parallel with the elaboration of the preliminary consultation document to substantiate the SSLE.
- For the evaluation of the impacts of continued operation, a well-substantiated impact assessment can be provided with respect to most specialist areas, because the data from detailed specialist surveys connected to the environmental licensing of the Paks NPP’s previous service life extension and output enhancement are accessible and usable, as are the results of the mandatory monitoring activities specified in the environmental license. Nearly a decade later, serving as a basis for preparing the environmental impact assessment required for the environmental licensing of the new NPP units to be established at the Paks site (Paks II NPP), further surveys, measurements, and analyses were conducted within the assumed impact area of Paks II NPP; since this area significantly overlaps with the impact area of the Paks NPP, the data obtained therefrom could likewise be taken into account when characterising the changes in the baseline environmental status.
  Within the impact assessment, based on the examination of the results obtained during the investigated periods and their variances, it was necessary to identify the causes of any changes and to filter out those impact factors that operated independently of the operation of the Paks NPP, as distinct from those that can be linked specifically to the impact factors associated with the NPP’s normal operational functioning.
- It is also a specific aspect of the conducted assessments that, alongside the Paks NPP’s site, in an area adjacent to the territory of the operational Units 1-4, the two new units of the Paks II NPP (Units 5 and 6) are being constructed as an investment by Paks II. Atomerőmű Zrt., which is an entity independent of MVM Paksi Atomerőmű Zrt. Based on the planned schedule for implementing the new units and the circumstance that activities belonging to the construction phase and resulting in significant environmental impacts will conclude by the initial period of the SSLE, the present EIAR concerning the SSLE period has evaluated the impacts of the joint operation of the two power plants. Accordingly, in addition to the independent assessment of the effects imposed by the Paks NPP, an evaluation of the cumulative impacts arising from the joint operation of the six power plant units (Paks NPP’s four existing and Paks II NPP’s two new units) was also carried out. The impacts, acceptability, and permissibility of the Paks NPP’s operation prior to the SSLE period and of the construction of the Paks II NPP were evaluated in the EIAR pertaining to the Paks II NPP. The impacts of changes occurring during the installation of the new units, whether

regarding technical content, or scheduling, can be treated as a review of those assessments.

- In the case of NPPs, decommissioning (dismantling) is an activity subject to a mandatory independent impact assessment pursuant to Government Decree 314/2005. (XII. 25.); consequently, the description of this phase is confined to a conceptual presentation as part of the present environmental licensing procedure.
- Activities related to the disposal of spent fuel and radioactive waste generated during the SSLE, carried out by an independent, standalone organisation (Public Limited Company for Radioactive Waste Management /PURAM/) separate from MVM Paksi Atomerőmű Zrt., shall be authorised in the framework of separate environmental licensing procedures. This EIAR presents the information concerning the interim storage of spent fuel generated during the SSLE and the final disposal of radioactive waste (similar to the decommissioning of the NPP) solely for descriptive purposes.
- It follows from the aforesaid that the delineation of the impact area must also depart from conventional practices. Pursuant to the legislation, *"direct impact areas are the areas attributable to specific impact factors, which may encompass the propagation areas of particular material or energy emissions into the soil, water, or air within the affected environmental medium, as well as areas subject to the direct use (land occupation) of ground, water, flora and fauna, or the built environment, and areas of anticipated landscape transformation"*. Furthermore, the impact areas of indirect impacts are defined as "*the propagation areas of consequential impact chains resulting from changes in environmental status within the direct impact areas, classified by the environmental elements and systems affected by a given impact process"*. As demonstrated in the statutory quotation, the impact zone is invariably linked to the spatial extent of a demonstrable change in environmental status. In the present case, no changes in environmental status characterised by significant spatial extent are anticipated. Consequently, the delineation of the impact area had to be fundamentally based upon the demonstrable, calculable, and modellable areas of status change associated with the baseline conditions and current operations. At the same time, the calculable variations in environmental media also had to be taken into account in the impact assessment. Where any environmental medium or system necessitated the consideration of an impact area differing from baseline conditions during the service life extension, that has been detailed separately within the delineation of the impact area.

In the EIA, the reference date for the baseline data and general information regarding environmental status was 31 December 2024, which was adjusted and expounded upon in specific instances to accommodate the distinct analytical requirements of individual disciplines.

1.6. Methodology of preparing the environmental impact assessment

1.6.1. The logical process and phases of the impact assessment

The fundamental goal of assessing the environmental impacts is to predict and evaluate changes in specific environmental elements or systems due to the planned activity, based on changes observed in the final receptors. To this end, as a first step, the power plant technological process and its associated activities were reviewed in order to enable the identification of individual environmental impact factors (e.g. environmental material and energy discharges, waste generation, noise exposure, etc.). With knowledge thereof, the most critical aspect of the impact assessments was the review of the logical chain: “impact factor → direct impacts → indirect impacts, i.e. impact pathways → directly and indirectly affected entities, i.e. receptors → ultimate receptors”. Therefore, in order to perform the impact assessment estimations, the impact factors of the activity under review and the resulting impact pathways had to be identified, and the assessment area to be delineated first. The changes in environmental status were estimated according to the following steps:

- Review of the planned activity (technology, operational processes, material consumption, associated activities, and environmental discharges).

- Identification of environmental impact factors.
- Mapping of impact pathways.
- Preliminary delineation of the assumed total impact area, i.e. the assessment area.
- Description of the environmental status (establishing the sensitivity of potential receptors),
- Estimation of impact pathways and changes in environmental status.
- Evaluation of status changes, final delineation of impact areas by environmental element, aggregation of the delineated elementary impact areas, and determination of the total impact area of the planned activity.
- Proposals for the avoidance and mitigation of adverse impacts.

During the preparation of the preliminary consultation document, an initial estimation of the expected environmental impacts of the SSLE and the impact area was carried out, which has been refined and supplemented in the current EIAR in light of the results of the completed specialist analysis programs.

For the purpose of assessing the baseline environmental status at the NPP site and its surroundings and executing the analyses necessary to substantiate the EIAR, 13 discipline-specific study programs were carried out.

Within the framework of executing the study programs encompassing both radiological and conventional disciplines, the results and documents of previous environmental analyses conducted for the site (in connection with both the operation of the Paks NPP and the construction of Paks II NPP) were collected, processed, and evaluated. Furthermore, the analysis programs extended to the completion of all specialist analyses (on-site measurements and sampling, model calculations, data processing, and assessments) that are indispensable for the preparation of the EIAR.

In the EIAR, the estimation of the environmental impacts anticipated in connection with the SSLE is based, on the one hand, on the results of environmental monitoring conducted during the NPP's operation to date, on operating experience, and on the results of previously performed analyses and model calculations, and, on the other hand, on the results of new on-site measurements, sampling, and analyses carried out in the framework of the study programs. Based on their content and level of detail, these data and information have provided an adequate professional basis for the preparation of the present EIAR.

1.6.2. The used main documents

In compiling the EIAR, the following primary documents were utilised as baseline data sources:

- The environmental license currently in force for the Paks NPP's operation, including its subsequent amendments.
- Documentation pertaining to the EIA for the first service life extension of the Paks NPP:
  - Discipline-specific final reports of the site characterisation program substantiating the EIA for the first service life extension (2002-2006).
  - The EIAR for the first service life extension.
- The Final Safety Analysis Report (FSAR) currently in force for the Paks NPP.
- The annual (environmental and radiological protection) reports of MVM Paksi Atomerőmű Zrt., alongside its periodic reports, data submissions, and environmental monitoring data provided to the environmental authority.
- Internal environmental regulations and procedural protocols of MVM Paksi Atomerőmű Zrt.
- Documentation relating to the implementation of the Paks II NPP:
  - The EIAR and its addenda for the implementation and operation of the Paks II NPP.
  - Nuclear safety site licensing documentation for the Paks II NPP (Site Safety Report and its addenda).
  - The First-Concrete Preliminary Safety Analysis Report of Paks II NPP.
  - Data supply by Paks II. Atomerőmű Zrt.

- Official statistics and repositories (e.g. the online databases of the Hungarian Central Statistical Office, and the national road traffic database).
- Maps and satellite images.

1.6.3. Classification and criteria of environmental impacts

The primary factors considered during the classification of environmental impacts were as follows:

- Exceedance of a limit value or a specific threshold of another accepted regulatory framework.
- The spatial extent of the impact (a large geographic footprint may increase the number of receptors and, consequently, the significance of the impact).
- The temporal nature (durability) of the impact.
- The reversibility of the processes.
- The feasibility of preventing or mitigating the development of adverse or detrimental impact chains.
- The reliability and uncertainty of estimations.

In the impact assessments, the evaluation of changes predicted as a result of estimated environmental impacts cannot always be expressed quantitatively (e.g. modifications occurring within ecological communities). Consequently, qualitative classification categories had to be generally introduced. In the present assessment, classification categories pertaining to the internal status changes of environmental media, typically used in impact statements, were applied to estimate the variations. The general classification of status changes applied in this impact assessment is presented in *Table 1.6.3-1*.

Table 1.6.3-1. General classification categories applied to status changes caused by environmental impacts

Classification	Explanation
Eliminating	This category encompasses changes whereby an environmental element, system, or any evaluation unit thereof considered independent, or the entirety of the element and system, or any independent component of the element or system, ceases to exist. It also includes instances where the element or system loses the specific characteristics that determined its classification (e.g. when agricultural land ceases to function as such due to urban development).
Damaging	This category presupposes the concurrent manifestation of two distinct factors. The first entails the exceedance of the relevant limit value, regulatory provision, or equivalent standard, thereby resulting in the downgrading of the environmental medium in question into a lower quality class. This does not necessarily mean the infringement of thresholds codified into legal instruments. The second condition is the irreversibility of the change, specifically, that the consequences of the change can only be rectified through human intervention. (The internal processes, self-purification mechanisms, and regenerative capacity of the given environmental medium are no longer capable of facilitating recovery.) Variations that are temporary yet periodically recurring (e.g. daily peak loads) are likewise deemed irreversible, and are consequently assigned to the detrimental category.
Burdensome	Two distinct cases may be assigned to this category: The first comprises instances where the aforementioned irreversibility applies, yet the variation does not entail the breach of a limit value or any other classification threshold. The second case involves scenarios where a threshold breach does occur, but the impact remains reversible without dedicated intervention. This is either because the impact factor is a single, non-recurring event, or because the impacts manifest continuously but with a negligible intensity.
Tolerable	This applies where undesirable variations are demonstrable (e.g. occasional or minor emissions approaching the limit value), yet these do not affect any essential characteristic of the given assessment unit. In these instances, prolonged or frequent exceedance of limit values is entirely precluded. Empirical evidence indicates that these variations are generally confined to a localised area.

Classification	Explanation
Neutral	This category encompasses impacts whose existence is verifiable, yet the induced change is of such a minor scale as to be imperceptible. Strictly speaking, a neutral impact equates to an absence of effect and is applicable solely to abiotic media; for living organisms and ecological systems, it is preferable to employ the terms no impact or non-detectable.
Improving	This category comprises variations that favourably alter a quantitative or qualitative attribute of an environmental medium or system. This classification includes all enhancements where no novel environmental value is generated, but rather the magnitude of existing values is amplified.

In the impact assessment, alongside the aforementioned classification of status changes induced by individual environmental impacts, their duration and significance were also evaluated. Based upon their temporal nature (durability), anticipated environmental impacts are categorised as short-term (up to a few months), medium-term (up to 3 years), or long-term (exceeding 3 years). In terms of severity, the impacts are designated as being of low, medium, or high significance. Impacts classified as either stress-inducing or of high significance correspond to a significant impact as defined pursuant to Government Decree 314/2005. (XII. 25.).

1.6.4. Assessment of the implementation of interlinked activities

Pursuant to Section 2 (2) e) of Government Decree 314/2005. (XII. 25.), an interlinked activity is defined as an activity identical to one specified in Annex 3 and falling under Annex 1 or 3 of the Decree[3], which the licensee plans to commence on the same or an adjacent property as said activities for a common investment objective, provided that it qualifies as an activity under Annex 3, or falls below the threshold defined in Annex 3 but, upon commencement, satisfies the threshold defined in Annex 3 when aggregated with the activity falling under Annex 1 or 3.

The proposed SSLE of the Paks NPP falls under Annex 1 (Point 31) of the Government Decree, meaning that it constitutes an activity subject to a mandatory EIA in its own right, irrespective of size thresholds. Following the commencement of the SSLE, no initiation of other activities falling under Annex 1 or 3 of the Government Decree is planned at the Paks NPP site in connection with the operation of the power plant.

The following activities, falling within the scope of Government Decree 314/2005. (XII. 25.), are currently ongoing or are planned on the properties adjacent to the site of the Paks NPP:

- Interim Spent Fuel Storage Facility (SFISF) /an operating nuclear facility/:
  - Classification under Government Decree 314/2005. (XII. 25.): Annex 1, Point 17: "*Interim or final storage facility for spent nuclear fuel*" (without threshold or size constraints).
  - Licensee: Public Limited Company for Radioactive Waste Management (PURAM).
  - Ref. No. of the license in force: 1449-42/2025 (environmental operational license issued by the Baranya County Government Office on 3 June 2025).
- Paks II NPP /a nuclear facility under construction/:
  - Classification under Government Decree 314/2005. (XII. 25.): Appendix No. 1, Point 31: "*Nuclear power plant, nuclear reactor*" (without threshold or size constraints).
  - Licensee: Paks II. Atomerőmű Zrt.
  - Ref. No. of the license in force: 78-140/2016. (environment protection license issued by the Baranya County Government Office on 29 September 2016).

Consequently, the activities conducted on the property adjacent to the Paks NPP site are in themselves subject to license issued by the environmental authority, and the licensee for both facilities is an autonomous corporate entity independent of MVM Paksi Atomerőmű Zrt. The adjacent Paks II NPP, constituting an identical activity, is likewise subject to a mandatory impact

[3] Annex 1 to Government Decree 314/2005. (XII. 25.) itemises activities subject to a mandatory environmental impact assessment, Annex 2 itemises activities subject to an integrated environmental use permit, whilst Annex 3 sets forth activities subject to an environmental impact assessment conditional upon the decision that the environmental authority takes during the preliminary examination procedure.

assessment without threshold or size constraints; its developer is Paks II. Atomerőmű Zrt., which holds a valid environmental permit for the facility.

Furthermore, the existing Paks 400/120 kV transformer substation, operated by MAVIR Magyar Villamosenergia-ipari Átviteli Rendszerirányító (Hungarian Transmission System Operator Company) Zrt., is located on a property adjacent to the Paks NPP. Pursuant to Point 127/A of Annex 3 to Government Decree 314/2005. (XII. 25.), the implementation of a transformer substation is subject to a examination procedure if it is situated within a protected natural area or a Natura 2000 site. Although the existing Paks transformer substation does not affect any protected areas, it falls under Annex 3 to the Government Decree (point 128.) under current regulations due to its land take exceeding 2 hectares and its zoning classification (developed area or area designated for development), which corresponds to "*other structures or complexes of structures not falling under Points 1-127/A in developed areas or areas designated for development, from a land take of 2 hectares"*. However, the transformer substation constitutes an existing, standalone facility whose license holder, MAVIR Zrt., is an autonomous company independent of MVM Paksi Atomerőmű Zrt.

The planned extension of the transformer substation will be implemented between 2026-2030, and the licensing of this is the responsibility of MAVIR Zrt.

Based on the above, no other activity of identical nature is planned either at the deployment site of the Paks NPP's SSLE (the assessed activity) or on adjacent properties which, when aggregated, would cause the activity evaluated in this EIAR to satisfy the specific thresholds prescribed under Annex 1 or Annex 3 to Government Decree 314/2005. (XII. 25.). No new linear infrastructure (e.g. overhead power lines, roads, railway tracks, or canals) is planned in connection with the implementation of the proposed SSLE.

Consequently, the implementation of interlinked activities in relation to the SSLE of the Paks NPP will not arise. Furthermore, the EIAR and other documentation pertaining to the individual facilities examine and evaluate the cumulative impacts of each facility.

1.6.5. Structure and layout of the EIAR

The EIAR for the Paks NPP's SSLE encompasses examinations, analyses, and model simulation tasks covering a wide range of subject areas, which were carried out through the coordinated efforts of multiple technical disciplines (engineering, environmental and nature conservation, radiation protection, meteorology, hydrology, etc.) and an extensive circle of experts. The objective of the EIAR presenting the results of the impact assessment was to deliver the extensive findings of the analyses performed by the individual technical sub-disciplines, available not only as textual information but also in the form of tables, diagrams, maps, figures, photographs, and measurement logs containing calculation and modelling results, in a transparent and structured manner, including the presentation of other statutorily required content elements. To this end, the EIAR is accompanied by discipline-specific annexes, each covering a specific subject area, while the documentation supporting the environmental permitting process also includes a Public summary of the EIAR and an international chapter, which is likewise statutorily required.

The EIAR has been compiled in accordance with the statutory requirements (as set out in Annexes 6 and 7 of Government Decree 314/2005. (XII. 25.)), as well as the content requirements set forth in the environmental authority's opinion concluding the preliminary consultation:

- Chapter 1 summarises the background, presenting the comments made by the authorities and other involved bodies during the preliminary consultation, as well as those received from the public, and introduces the professional organisations and institutions participating in the development of the EIAR, assigned to their respective technical fields,
- Chapter 2 describes the planned activity, including a detailed description of the site, the power plant's technological process, along with the associated operations and facilities,
- Chapter 3 identifies and presents the environmental impact factors and impact processes to be studied,
- Chapter 4, based on the results of the studies conducted by the individual technical fields, presents and evaluates the expected conventional environmental impacts arising from the

preparation and implementation of the planned activity, including their evaluation and classification, broken down by environmental elements and systems,
- Chapter 5 presents and evaluates the characteristics of environmental radioactivity and the changes anticipated due to the service life extension,
- Chapter 6 reviews the environmental impacts of the NPP's decommissioning,
- Chapter 7 presents the impact areas delineated for the expected environmental impacts in the form of maps, both by environmental element and in aggregate,
- Chapter 8 examines and evaluates potential transboundary environmental impacts,
- Chapter 9 presents the environmental measures proposed for the SSLE period.

The independent discipline-specific annexes, prepared by the individual professional organisations and expert groups, serve as the basis for the findings and conclusions of the EIAR. Such annexes provide a detailed presentation of the statutory and other requirements applicable to the given technical assessment, the primary data used, and the data sources, including an overview of the analytical methodology applied. The discipline-specific annexes describe the environmental baseline characteristics considered for the given assessment, as well as details of the examination into the environmental impacts anticipated due to SSLE, the analytical results, findings, and conclusions. The discipline-specific annexes fully document the results of the impact analyses performed in the following areas of examination:

- impacts on air quality,
- climatic characterization of the site,
- impacts on surface waters (and on aquatic life),
- local assessment of impacts on the groundwaters and the geological medium,
- regional assessment of impacts on groundwater,
- impacts on the biosphere and the ecosystems (Natura 2000 impact assessment),
- impacts on the landscape, land use and municipal environment,
- waste management,
- impacts on the noise and vibration levels,
- social and economic impacts,
- current radiological state of the site and its environment,
- radiation exposure of the population,
- health status of the population,
- radiation exposure of wildlife.

The public summary of the EIAR presents the planned activity and its expected environmental impacts to the domestic and international public, in accordance with the requirements set out in Annex 6 of Government Decree 314/2005. (XII. 25.).

Linked to the public summary, an international chapter, compiled as an independent document and referred to pursuant to Section 14 (1) of Government Decree 314/2005. (XII. 25.), presents the detailed results of examinations into potential transboundary environmental impacts, as well as a summary of the comments and questions submitted by countries notified within the framework of the preliminary consultation along with the responses provided thereto.

Figure 1.6.5-1 illustrates the layout of the EIAR documentation and the interrelations between its individual components.

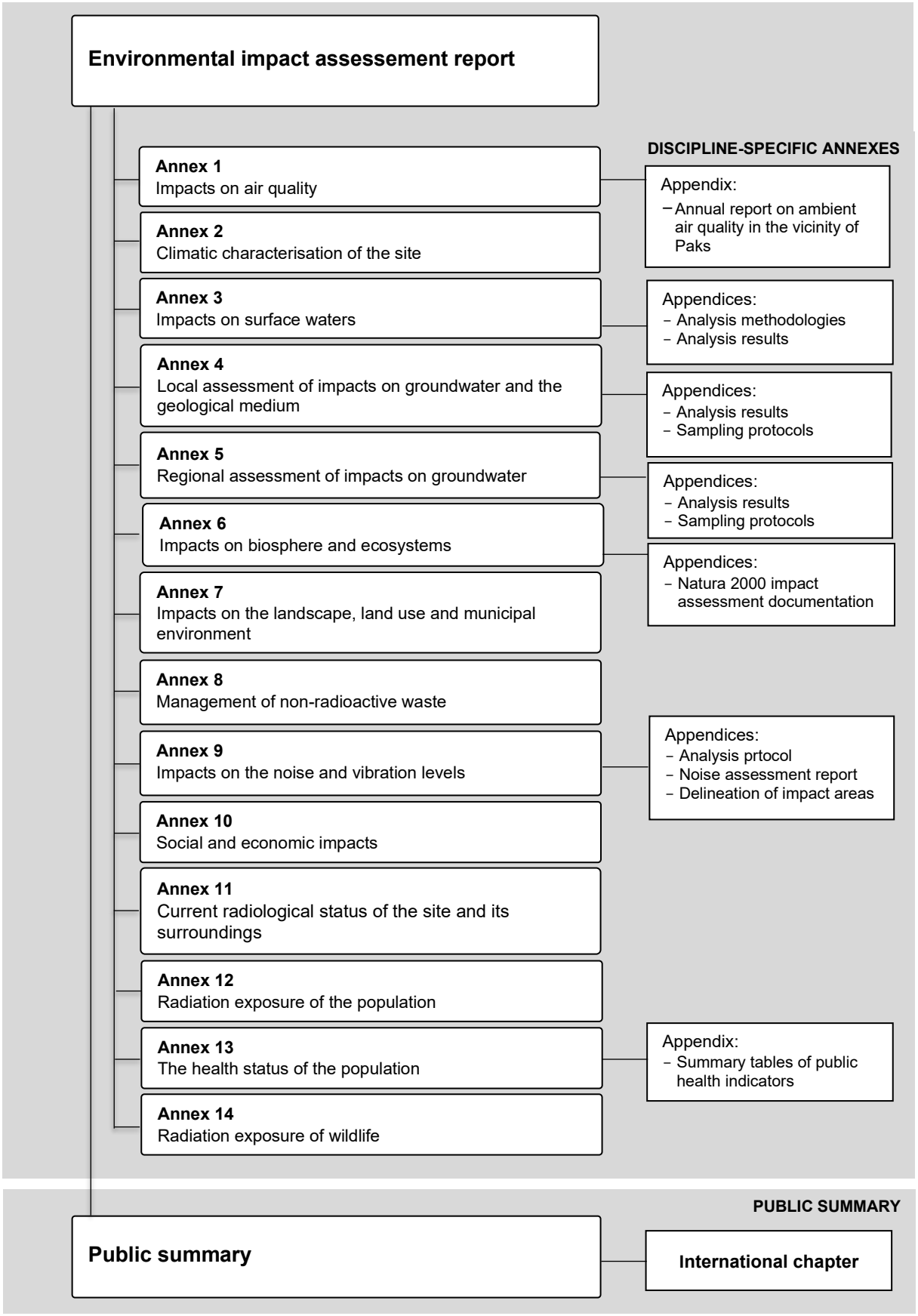


Figure 1.6.5-1. Structure of the EIAR documentation

1.6.6. Use of classified data and commercially confidential information

Neither the present EIAR, nor its associated discipline-specific annexes contain any classified data or commercially confidential information. The data and information presented in the documentation are fully accessible to the public; the documentation does not contain any restricted, separated sections.

1.7. International status and practice of plant service life extensions

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 PWRs and VVERs). A review of the activities of several leading countries demonstrates a clear and consistent trend.

The U.S. 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 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.

2. The SSLE, the site of the NPP and the technology of nuclear energy production

2.1. The site of the NPP and its surroundings

2.1.1. Geographical location of the site

The Paks NPP site is located in the southern Transdanubian region, on the eastern border of Tolna county, 1 km west of the River Danube, at 1,527 rkm, and 1.5 km east of Main Road No. 6. The site is located 118 km south of Budapest, 5 km south of the city centre of Paks. The nearest national border section is located to the south, 63 km in a direct line, 94 km downstream of the Danube, the national border stretches at rkm 1,433. The area of the circle with a 30 km radius designated for the assessment of the NPP's wider surroundings covers the area of Bács-Kiskun, Fejér and Tolna counties, and within these 75 settlements, for a total area of 282,743 ha (*Figure 2.1.1-1.*). The wider – 30 km radius zone – surroundings of the power plant site are shown on an overview map in *Figure 2.1.1-2.*

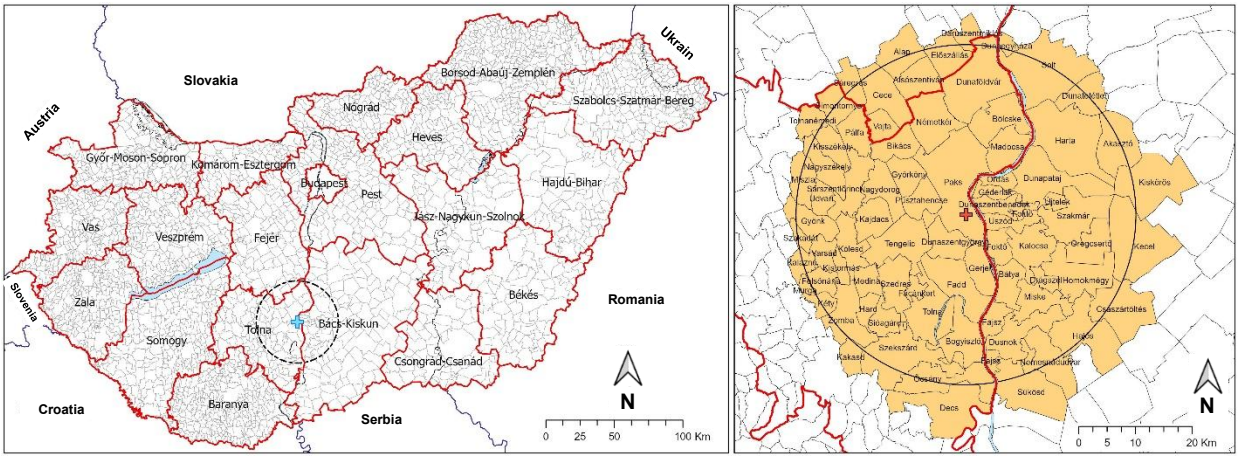


Figure 2.1.1-1. Geographical extent of the assessment area

The designated area (Paks region) is divided into two parts by the Danube. The full area in the Duna-Tisza Midland, as well as the eastern and central parts of the Transdanubia (Mezőföld) belong to the great region of Great Hungarian Plain of plain nature, while its western part forms part of the great region of Transdanubian Hills of hilly nature (*Figure 2.1.1-3.)*.

The aforementioned two great regions (Great Hungarian Plain, Transdanubian Hills) consist of a mosaic of small regions, which are essentially similar to each other, but differ in some parameters. Small regions of Solti-sík (16,385 ha), Kalocsai-sárköz (89,790 ha), Bugaci-homokhát (6,636 ha), Közép-Mezőföld (29,310 ha), Dél-Mezőföld (50,157 ha), Tolnai-sárköz (33,923 ha) and Sárvíz-völgy (16,174 ha) belong to the Great Hungarian Plain. The relevant part of the Transdanubian Hills can be divided into Tolnai-hegyhát (36,341 ha) and Szekszárdi-dombság (4,026 ha). The site is located at the boundary between the small regions of Dél-Mezőföld and Tolnai-sárköz.

In terms of topography, the bigger part of the site's surroundings is perfect flatland. The rest of it comprises a flat, gently undulating plain landscape, and a portion of hilly landscape. The average terrain level in the surroundings of the right and left banks of the Danube is 93-94 m. In addition, there are gently undulating areas covered with loess in the west and northwest, where the highest point is near Györköny (214 m), as well as hilly areas where the highest point is near Szekszárd (255 m).

The geographical location and characteristics of the site are considered to be constant as measured on a geographical scale and are not expected to change in the future.



Source: National Geospatial Base Map (NTA), Lechner Knowledge Centre

Figure 2.1.1-2. The site and its wider surroundings (with a 30 km radius) of the Paks NPP

In the 30 km zone (Paks region), the extent of Natura 2000 and nationally protected areas is significant. The Special Bird Protection Areas belonging to the Natura 2000 network cover a total of 26,603 ha, while the extent of the Special Nature Conservation Areas is 42,495 ha. Taking into account territorial overlaps, the extent of the Natura 2000 areas within the assessment area covers 50,937 ha. The national parks and other protected areas cover an area of 20,243 ha. Due to territorial overlaps with the Natura 2000 network, the total size of the areas under national protection is 51,765 ha, which is 18.3% of the total area. *Figure 2.1.1-4.* shows the protected natural areas in the surroundings of the site.

In area of Paks, there are three protected areas of national importance, of which only one natural monument, the loess wall geological profile in Paks (2 hectares) is located entirely within the administrative area. The Dél-Mezőföld Landscape Protection Area and the nature reserve of Dunaszentgyörgyi láperdő affect Paks with a total of 604 ha. The area of the Natura 2000 areas within the settlement boundaries is 2,319 ha. The national protected areas and Natura 2000 Special Conservation Areas together cover 2,496 ha of the settlement area of Paks.

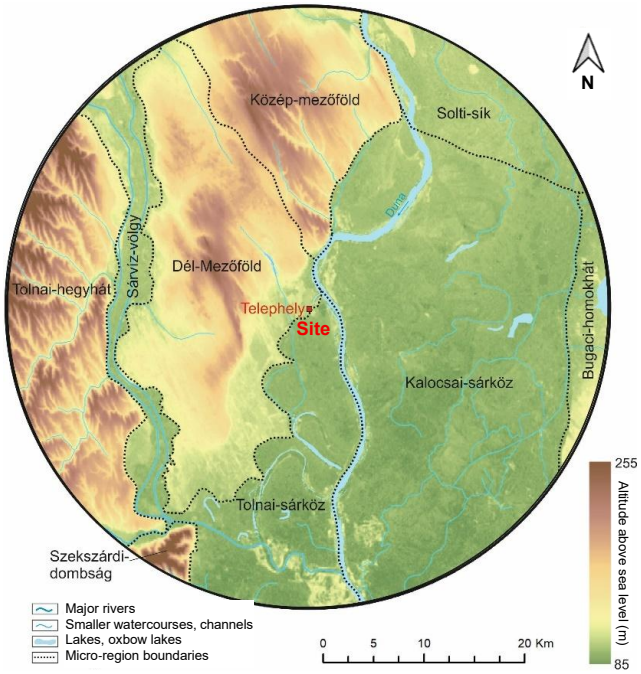
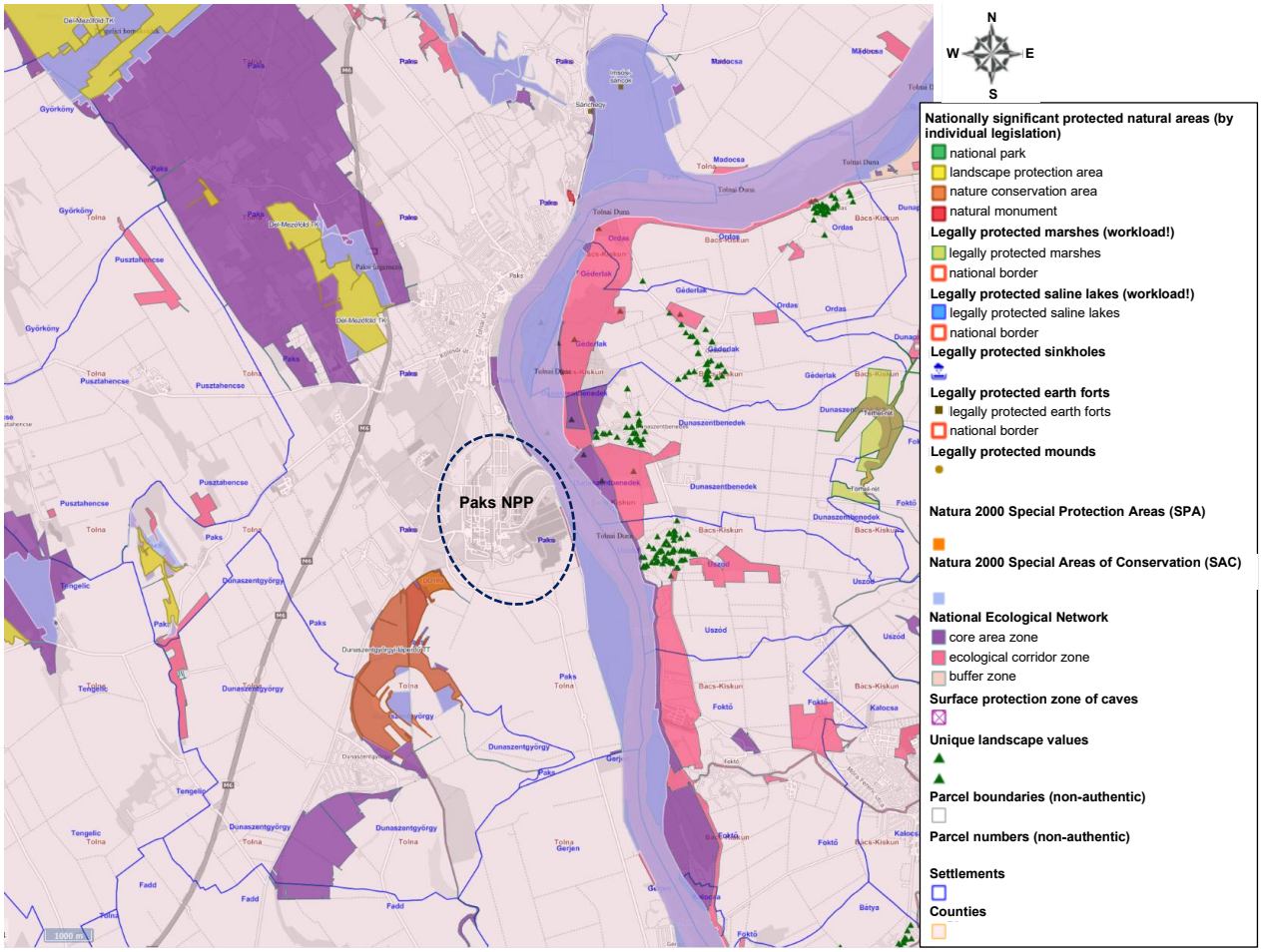


Figure 2.1.1-3. Physical geographical conditions of the survey area



Source: Nature Conservation Information System (TIR)

Figure 2.1.1-4. The protected natural areas in the surroundings of the Paks NPP site.

2.1.2. Land use of the site and its immediate surroundings

2.1.2.1. Design and area requirements of the site

The Paks site is located in the administrative area of the city of Paks, in an inland are, and its area is divided into the following three main parts:

- Operational area of the Paks NPP (plot number 8803/17):
  The units 1-4 operated by the MVM Paksi Atomerőmű Zrt., the associated turbine room, water intake structures, as well as the auxiliary equipment, systems, office, maintenance, and storage buildings required to support them are located in this part.
- Operational area of the Paks II NPP (plot number 8803/16):
  The area north of the existing units 1-4 of the NPP, which is the designated area for the location of the new Paks II NPP (Units 5-6), which is under construction by the Paks II. Atomerőmű Zrt. Construction work of the units 5-6 is currently underway in the investment area.
- Operational area of the Spent Fuel Interim Storage Facility (SFISF) (plot number 8803/2):
  In the area south-west of the operational area of the units 1-4, the SFISF and other buildings and structures connected to it are located, maintained by the Public Limited Company for Radioactive Waste Management (PURAM), as the holder of the nuclear facility permit.

The central EOV coordinates of the Paks NPP site: X: 136,667.09 m, Y: 635,005.39 m. The operational area of the power plant includes tailings ponds as well as the cold-water and warm-water channels. The location of the power plant's site and its immediate surroundings are shown in a satellite image marking the construction site of the Paks II NPP and the area of the SFISF in *Figure 2.1.2.1-1.* The layout of the power plant's site is shown in *Figure 2.1.2.1-2.* The buildings, structures and equipment of the Paks II NPP currently under construction, the new warm-water channel, the new substation belonging to the Paks II NPP and the constructions of the temporary works area were also indicated on the layout. The hazardous and industrial waste collection point at site connected to the Paks NPP is located on the construction site of the Paks II NPP. As the layout shows, the majority of the area between the existing cold-water and warm-water channel will be the operational area of the Paks II NPP's warm-water channel and its associated facilities. The installation area of the alternative warm-water channel section and its related peak cooling system structures and equipment planned to be constructed as part of the preparation of the Paks NPP SSLE are indicated on the layout (and also *Figure 2.1.2.1-1.).* The establishment of the latter is necessary during the period of joint operation of Paks NPP and Paks II NPP in order to ensure cooling – before the cooling water taken from the Danube and warmed by the technology will be returned to the river – and to reduce the thermal load of the Danube (Technical description of the planned transformation is given in *Chapter 2.2.2.1.*)

The operational area of the Paks NPP Units 1-4 is owned by the Paks NPP Ltd., the area of the Paks II NPP with cadastral number 8803/16 is owned by the Paks II NPP Ltd. The external area boundary of the areas of the Paks NPP and the parts that can be separated within the operating areas are shown in *Figure 2.1.2.1-3.* Besides the actual operational areas, the reserve operational area, the fishponds, the access routes and forests are to be considered as external areas. The *Table 2.1.2.1-1.* shows their current distribution in terms of size, i.e. the area required for the site of the NPP. Taking into consideration that the route of the planned new warm-water channel section (*Chapter 2.2.2.1.*) is located in the northern part of the area cadastral number 8803/11 used by the fish ponds, it is necessary to modify the area boundary between the two plots before constructing the canal section in order to bring the new canal section into the operational area with plot number 8803/17. As a result, the operational area of the NPP (plot number 8803/17) will increase with the size of the area used by the canal section and the area of the property affected by the fishponds (plot number 8803/11) will decrease by the same amount.

Within the site of the Paks NPP there is only activity related to nuclear energy production. Apart from this activity, there are no other activities affecting operational safety.

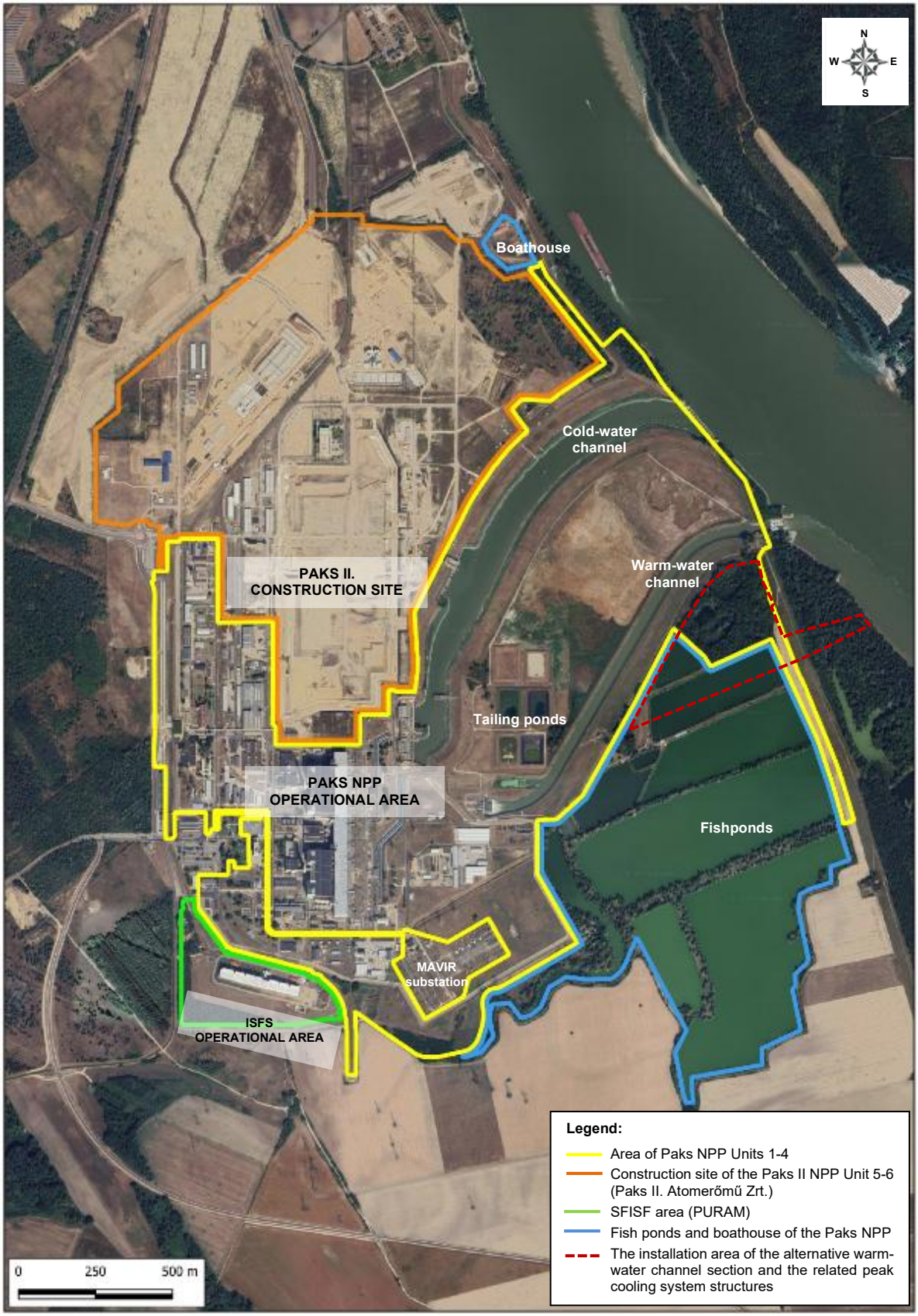


Figure 2.1.2.1-1. Satellite image of the Paks NPP site and its surroundings, marking the Paks II NPP construction site and the area of SFISF

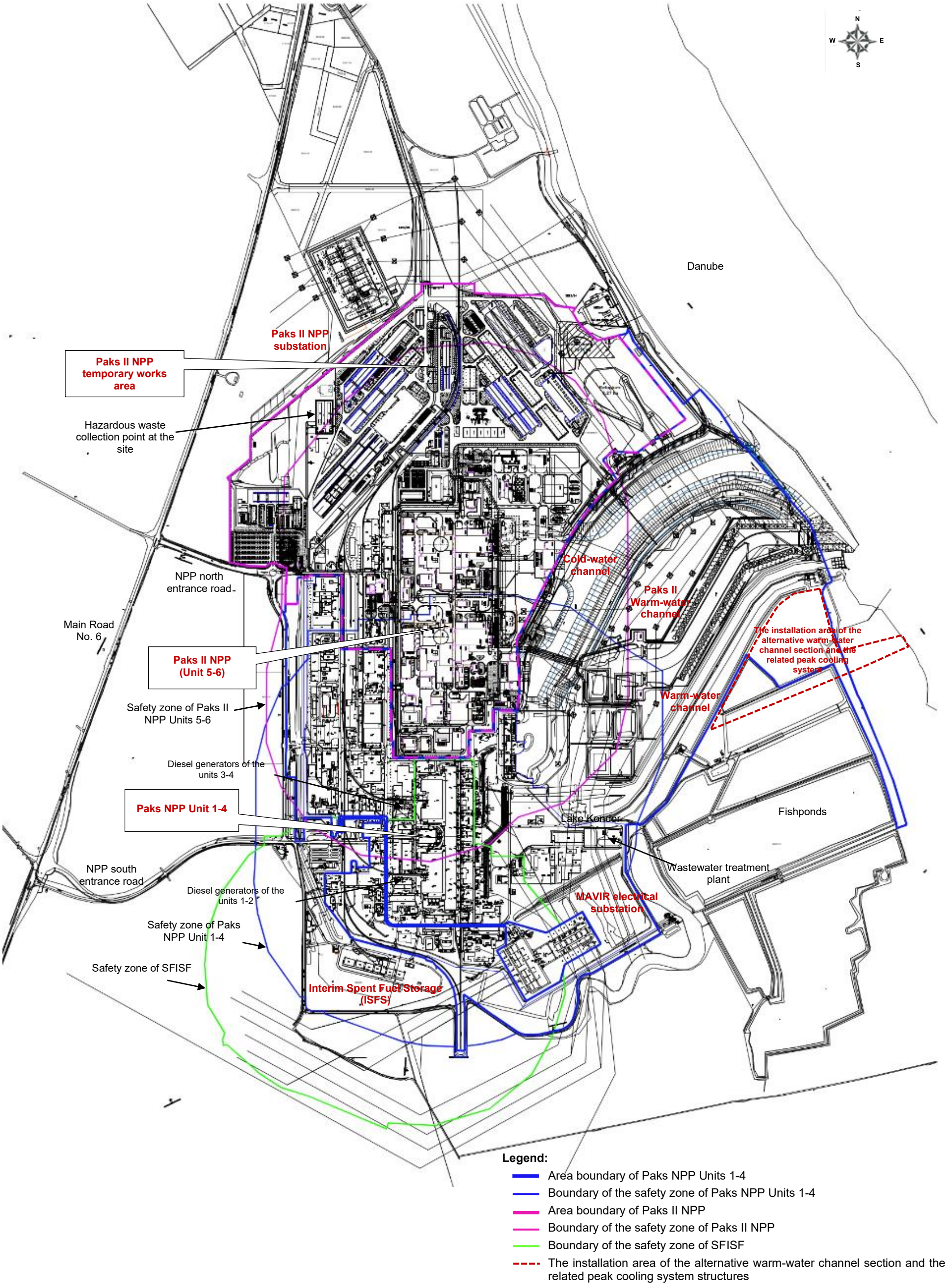
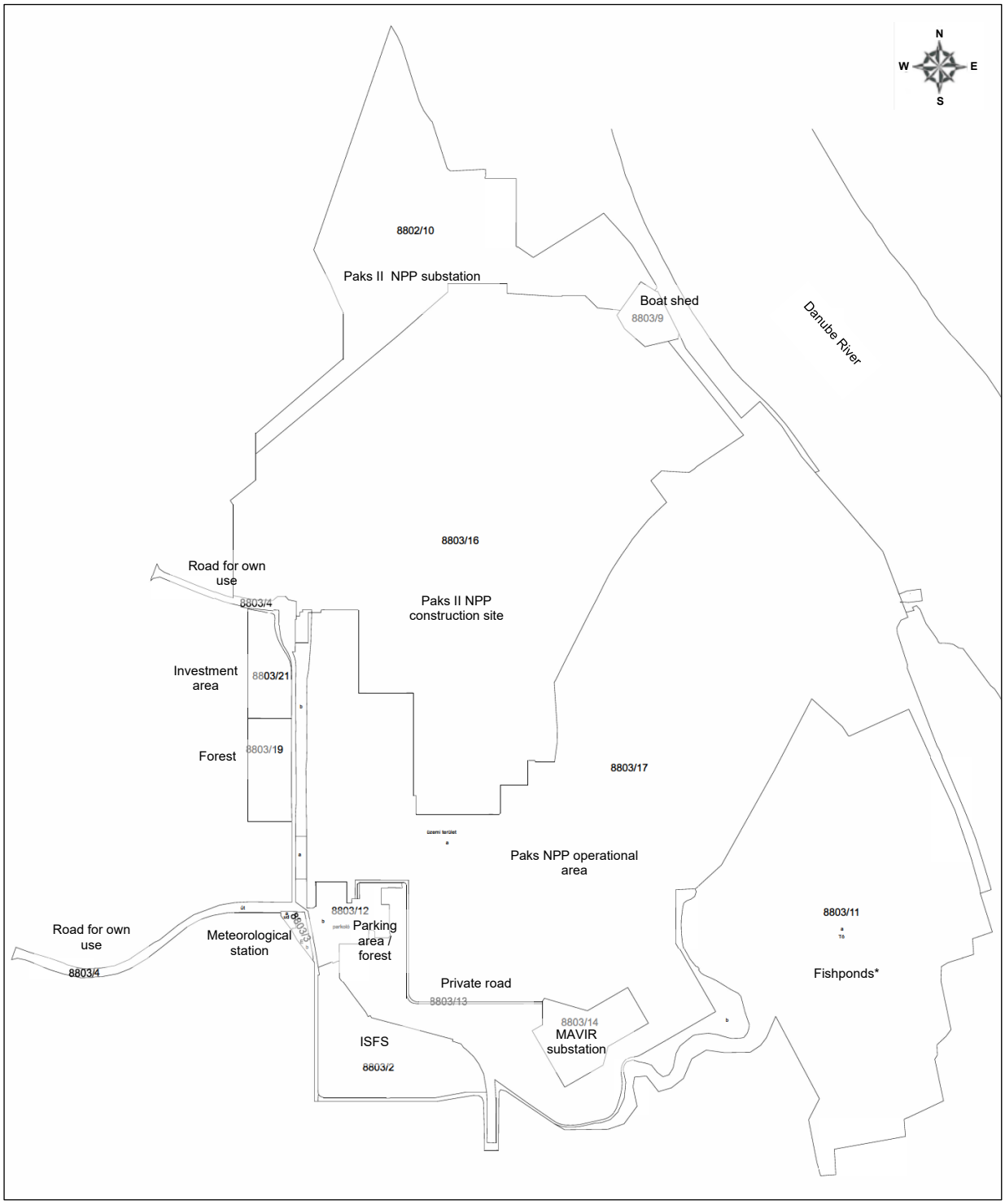


Figure 2.1.2.1-2. Layout of the Paks NPP and its immediate surroundings including the planned buildings of the Paks II NPP



* The route of the planned new warm-water channel section runs across the northern part of the land plot registered under plot number 8803/11, currently occupied by fish ponds; therefore, a boundary adjustment will be required prior to the construction of the channel section.

Figure 2.1.2.1-3. Boundary and internal area distribution of the Paks NPP

The area of the Paks NPP is surrounded by a safety zone, which is designated by the regulation of the Hungarian Atomic Energy Authority (HAEA) under the Government Decree 246/2011. (XI. 24.) on the safety zone of the nuclear facility and radioactive waste storage. The height of the safety zone above the surface is 500 m from the plane of the outermost technological protection wall of the NPP. The safety zone of the nuclear facilities in the aforementioned Government Decree may overlap. Persons continuously present at the boundary of the safety zone shall not

be exposed to more than 100 μSv/year by the radiation of the radioactive materials released or relocated to environment during the proper operation of the facility.

A safety zone of 500 m has also been designated around the areas of SFISF and Paks II NPP neighbouring the Paks NPP (*Figure 2.1.2.1-2).* In the safety zones, the restrictions laid down in the above-mentioned Government Decree apply.

Due to the SSLE of the Paks NPP, the construction of new buildings and structures related to the nuclear technology is not planned in the operational area of the NPP, so the scope of the currently designated safety zone is not affected by the planned activity.

Table 2.1.2.1-1. Operational area of the MVM Paksi Atomerőmű Zrt., and the data of neighbouring properties according to the real estate register

Plot number	Description		Area [ha]
8803/2	Subsection a	Excluded operational area (SFISF operational area maintained by PURAM)	11.3742
	Subsection b	Forest	2.4119
8803/3	Undeveloped area removed from cultivation (meteorological station)		0.7191
8803/4	Road for own use on an area removed from cultivation (access roads / northern, southern, link road/)		6.6368
8803/20	Area removed from cultivation for investment purposes		0.2538
8803/21	Area removed from cultivation for investment purposes		4.2682
8803/19	Forest		4.7664
8803/9	Boat shed		2.5271
8803/11	subsection a	Fishpond*	93.1596
	subsection b	Operational area removed from cultivation	5.8775
8803/12	subsection b	Parking lot removed from cultivation	5.3354
	subsection c	Forest	0.5057
8803/13	Private road removed from cultivation, closed for public traffic		0.6556
8803/16	Operational area removed from cultivation (site of Paks II NPP's Units 5-6, owned by Paks II. Atomerőmű Zrt.)		157.8856
8803/17	subsection a	Operational area (Units 1-4 of the Paks NPP)*	214.2264
	subsection b	Area removed from cultivation for investment purposes	2.4532

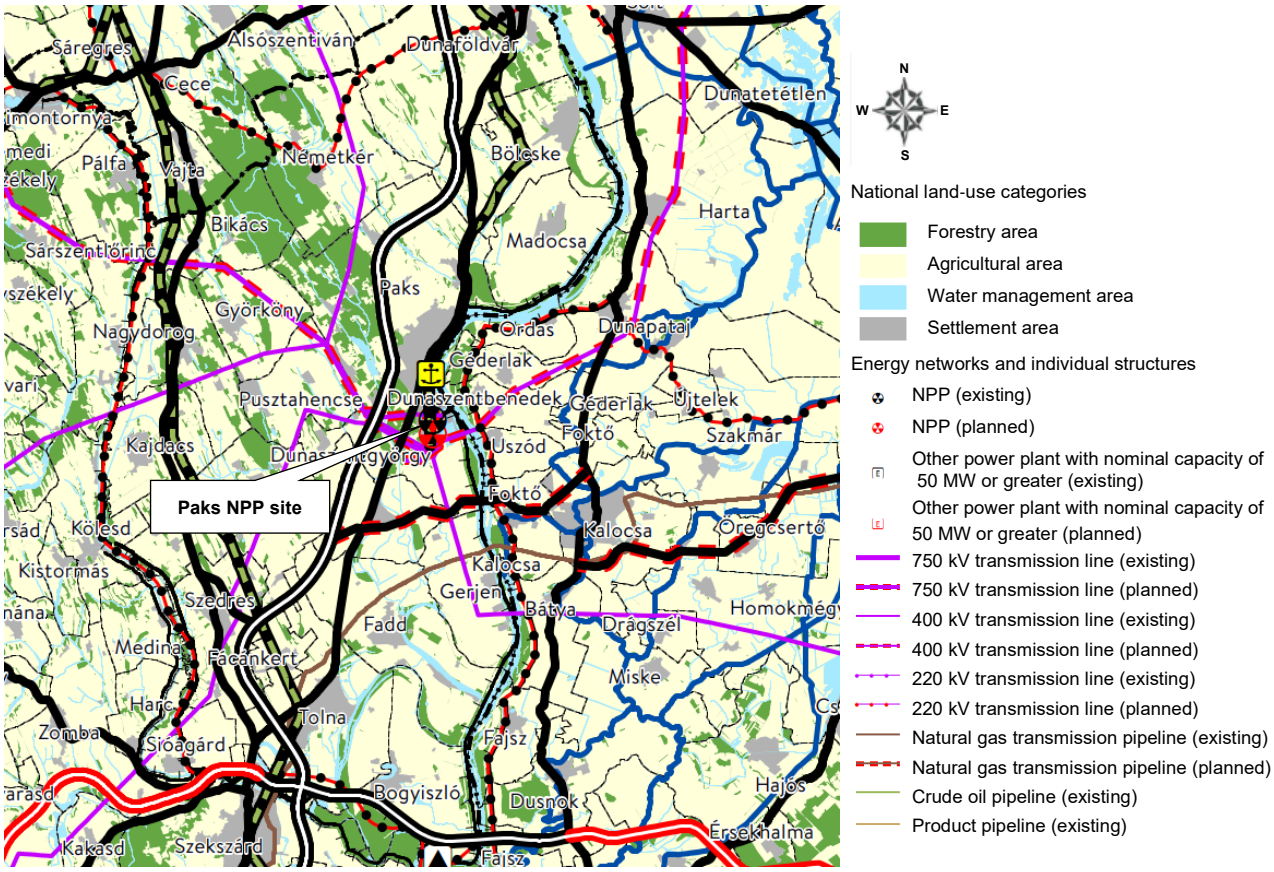
* The route of the planned new warm-water channel section runs across the northern part of the land plot registered under plot number 8803/11, currently occupied by fish ponds; therefore, a boundary adjustment will be required prior to the construction of the channel section. The areas 8803/17 a and 8803/11 a are expected to change.

2.1.2.2. Examination of land use and compliance with settlement planning regulations

The characterization of land use at the power plant site and its immediate surroundings, as well as the assessment of compliance with settlement planning regulations, are carried out on the basis of national and county-level spatial plans, as well as the Local Building Regulation (HÉSZ) with a presentation of the zones defined by the HÉSZ, taking into account the following legislation:

- Act CXXXIX of 2018 on the Spatial Planning Plan of Hungary and its Certain Priority Regions,
- Municipal Decree 8/2020. (X. 29.) of the General Assembly of the Municipality of Tolna County on the spatial plan of Tolna County,
- Decree 33/2016. (VIII. 22.) of the Local Government of Paks City on the Paks City's Local Building Regulation,
- Municipality Decision 92/2016. (VIII. 17.) of the Local Government of Paks City on the revision of the Paks City's Settlement Structure Plan, amended several times.

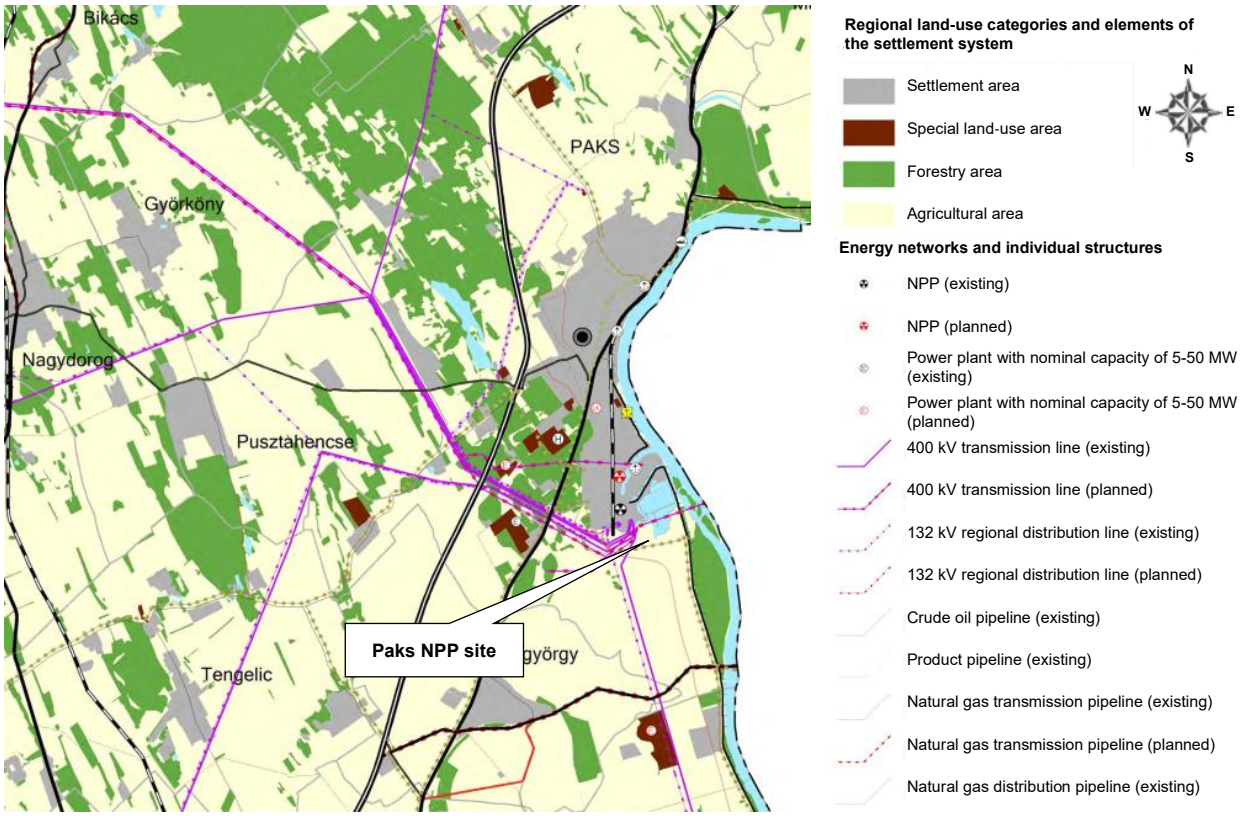
According to Point 1.13. of the Annex 4/7 to the Act CXXXIX of 2018 on the Spatial Planning Plan of Hungary and its Certain Priority Regions, the “Paks I.” is listed as the site of the existing NPP, which is also indicated in Annex 2 of the Act (the National Structural Plan) (*Figure 2.1.2.2-1.*). The continued operation of the NPP is, therefore, in accordance with the provisions of the National Spatial Plan (OTrT) and the National Structural Plan. Based on the National Structural Plan, the site of the NPP is surrounded by a settlement area to the north, a forestry area to the west, a forestry, agricultural, and water management area to the south, and a water management area to the east, where areas falling under the land-use category of forestry, agriculture, and settlement area are located. The site of the power plant falls under the land-use category of settlement area.



Source: Extract of Annex 2 to the Act CXXXIX of 2018, Lechner Knowledge Centre Territorial, Architectural and Informatics Nonprofit Ltd., Directorate of Spatial Services, April 2021.

Figure 2.1.2.2-1. The Paks NPP site in the National Structural Plan

In Point 2.8.1. of the Annex 1 to the Municipal Decree 8/2020. (X. 29.) of the General Assembly of the Municipality of Tolna County on the spatial plan of Tolna County, the “Paks I.” with a capacity of 2000 MW is listed as an existing power plant within the Tolna county’s technical infrastructure networks and individual buildings system, which is also indicated in the Annex 2 to the decree (Regional Structural Plan) (*Figure 2.1.2.2-2.*). Continued operation of the NPP is therefore in accordance with the provisions of the Tolna county’s spatial plan and the Regional Structural Plan. The land-use classification of the NPP site and the surrounding areas in the Regional Structural Plan corresponds to the classification specified in the National Structural Plan.



Source: Municipal Decree 8/2020. (X. 29.) of the General Assembly of the Municipality of Tolna County on the spatial plan of Tolna County, Annex 2: Regional Structural Plan extract

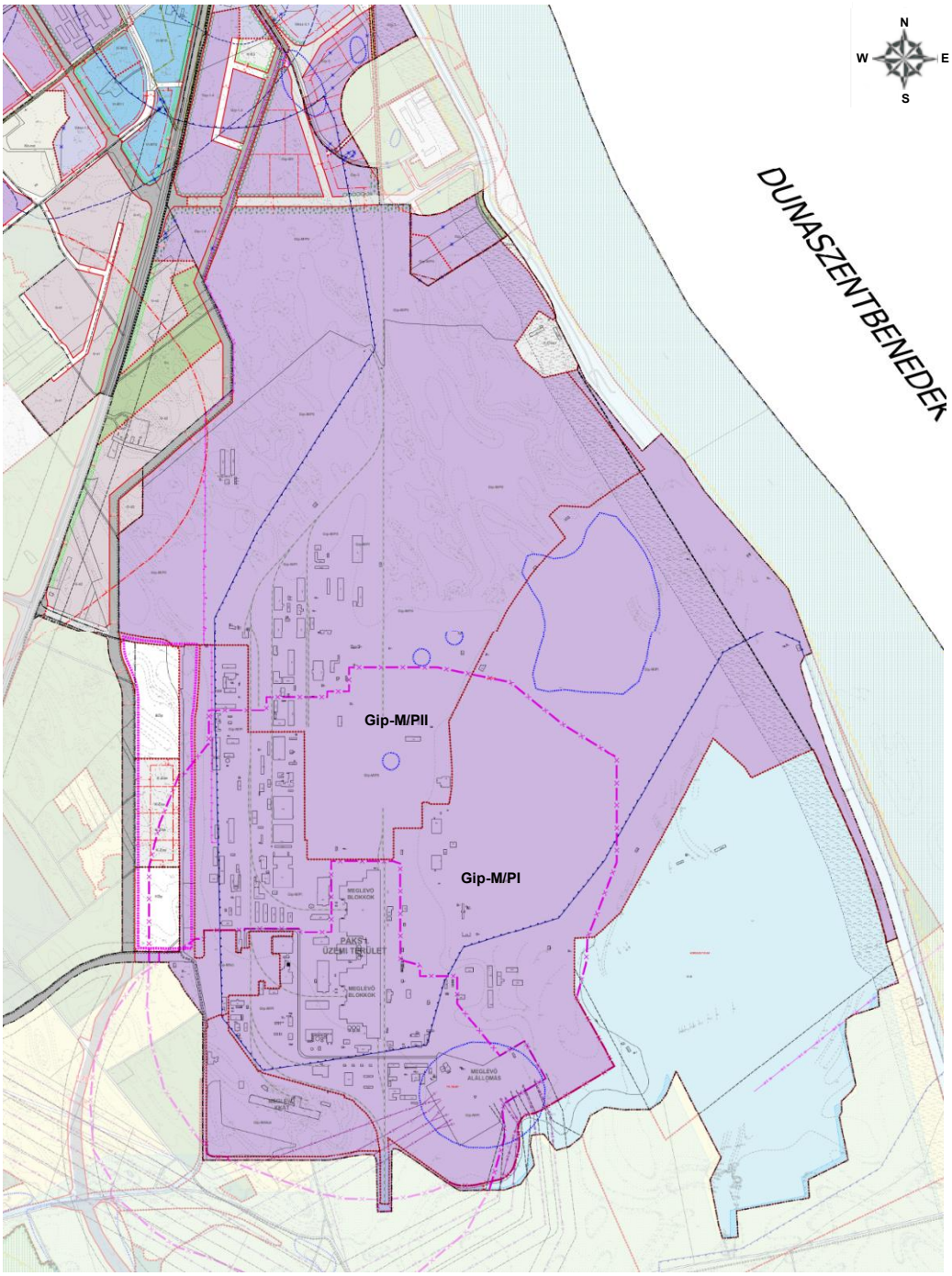
Figure 2.1.2.2-2. The site of the Paks NPP in the spatial plan of Tolna county

Based on sections B26-B27 of the urban zone regulation plan (*Figure 2.1.2.2-3.)*, which constitutes Annex 1/a to the Annex 1 to the Decree 33/2016. (VIII. 22.) of the Local Government of Paks City on the Paks City's Local Building Regulation (Paks City's Regulation Plan) (HÉSZ), the Paks NPP's operational area is located within the construction zone of the industrial-economic area marked as Gip-M/PI. The zone marked as Gip-M refers to the industrial-economic area for NPP (existing and new NPPs, existing and new substations, traffic areas, the interim spent fuel storage, and additional industrial-economic areas for NPPs' area). The zone marked as Gip-M is divided into the following construction zones:

- Gip-M/t refers to an industrial-economic area for NPP not directly connected to the NPPs' site,
- Gip-M/PI refers to the area of the existing NPP and the existing substation,
- Gip-M/PII refers to the area of the new NPP and the new substation,
- Gip-M/kkát refers to the area of the spent fuel interim storage,
- Gip-M/kö refers to the traffic area.

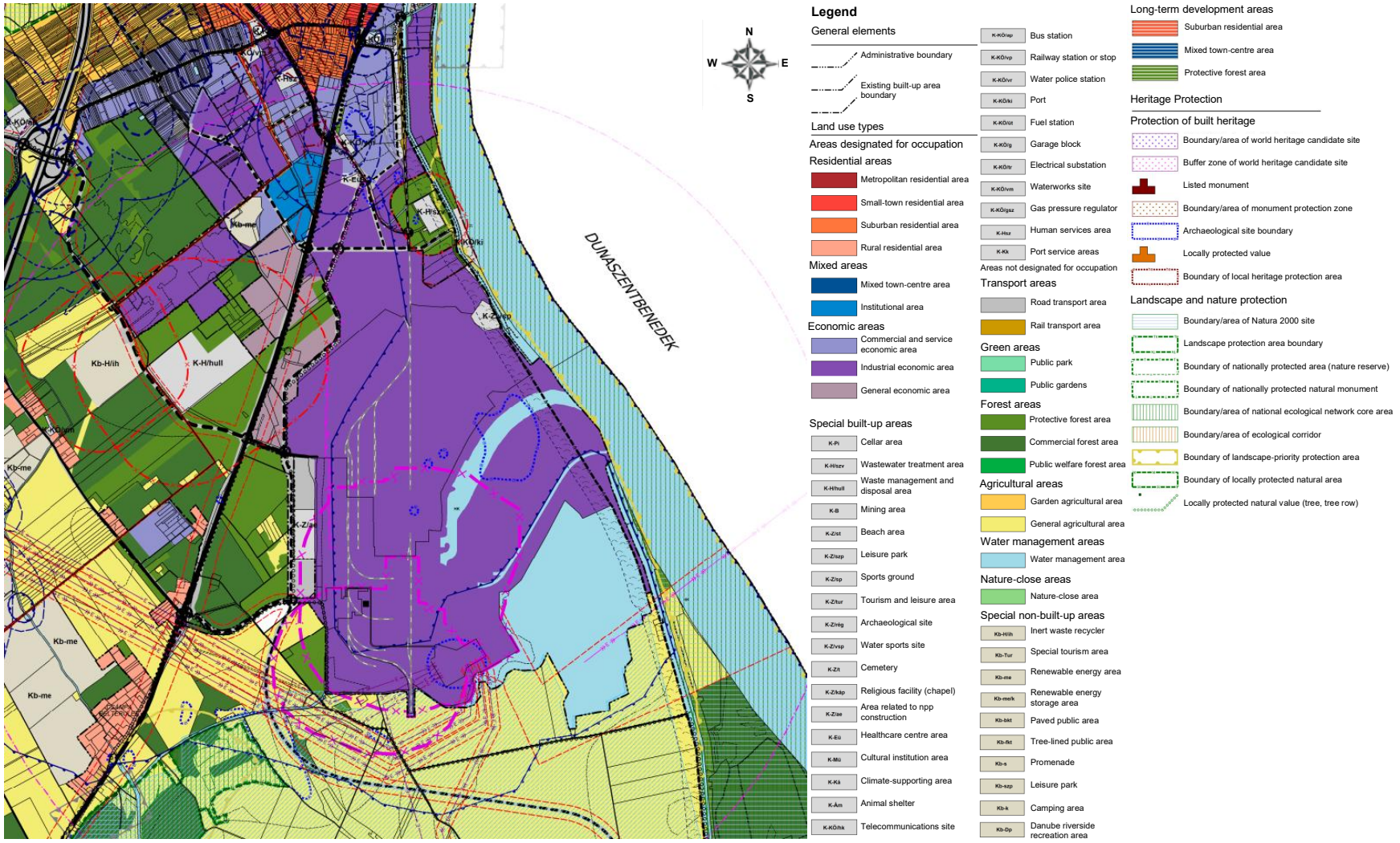
According to the provisions of the HÉSZ, the construction zone marked as Gip-M/PI encompasses the area of the existing NPP, as well as the area of the existing substation and the overhead electrical power line (overhead wires and cables) directly connected to it. The area may accommodate the existing and the new NPPs, as well as facilities necessary for the operation of the existing and new substations, and for the construction of the new NPP.

Figure 2.1.2.2-4. shows the Settlement Structure Plan of Paks, which was adopted by the Municipality Decision 92/2016. (VIII. 17.) of the Local Government of Paks City on the revision of the Paks City's Settlement Structure Plan, amended several times. The figure indicates that the operational area of the Paks NPP, together with the area of the Paks II NPP and the SFISF, is located in a zone classified as Gip – an industrial economic area.



Source: Based on sections B26-B27 of the urban zone regulation plan, which constitutes Annex 1/a to the Annex 1 to the Decree 33/2016. (VIII. 22.) of the Local Government of Paks City on the Paks City's Local Building Regulation (Paks City's Regulation Plan)

Figure 2.1.2.2-3. The site of the Paks NPP in the Paks City's Regulation Plan



Source: Municipality Decision 92/2016. (VIII. 17.) of the Local Government of Paks City on the revision of the Paks City's Settlement Structure Plan, amended several times (extract).

Figure 2.1.2.2-4. The site of the Paks NPP in the Paks City' Settlement Structure Plan

Figure 2.1.2.2-4. shows the existing or planned land-use categories near the power plant's site – as specified in the settlement planning documents, as follows:

- To the north: Gip-M/PII – industrial economic zone: the area of the Paks II NPP and its associated substation.
- To the east: River Danube – V-1 – water management area: bed and bank lane of the River Danube.
- To the south: Fishponds – V-6 – water management area: bed and bank lane of other running waters and stagnant waters Má-á – general (typically arable) agricultural zones, Má-k – restricted-use agricultural zones.
- To the west: Ev – forest areas designated for protection, KÖp – traffic areas designated for parking, Má-k – restricted-use agricultural zones.

On the basis of the above, it can be concluded that the current use of the area utilized by the Paks NPP and the use specified in the settlement planning documents are identical according to the foregoing. The route of the alternative warm-water channel section planned for construction as part of the SSLE preparation partially also includes water management areas (fishponds, the Danube riverbank strip) – according to the current zoning classification. It will, therefore, be necessary to amend the boundaries of the industrial economic zone marked as Gip-M/PI and the water management zone marked as V-6 so that the warm-water channel section can be located within the construction zone marked as Gip-M/PI. The section of the earth-banked channel located outside the NPP's property boundary will be constructed within the water management construction zone marked as V, where, according to the Paks City's HÉSZ, buildings shall only be placed in accordance with water management considerations, as specified in separate legislation. This section of the canal also affects a narrow forest area designated for protection marked as Ev. According to the HÉSZ, in forest areas, prior to designating specific construction sites, the site's tendency to surface movement shall be assessed from an engineering geological point of view. The designation of construction sites and the specific conditions for the construction of structures must be based on engineering geological and geotechnical examinations in areas may be affected by surfaces movements. Otherwise, the implementation of a SSLE of the NPP is in accordance with settlement planning tools at the existing site being operated.

The relationship to the assessment area and the Paks city was assessed based its role defined in the regional and settlement development documents as follows:

- The Tolna County's Regional Development Concept and Program 2021-2030 (2021) emphasizes the importance of the expansion of the Paks NPP, attributing significant social, economic, infrastructural, and environmental impacts to it, and considers its management a priority. The document supports the implementation of the Priority Area along the Central Danube's development plans in connection with the Paks expansion; therefore, it also includes the establishment of energy research and development partnerships, but also the economic diversification through the strengthening of traditional light industry.
- The Regional Development Concept of the Priority Area along the Central Danube 2021-2035 and the Strategic Program of the Priority Area along the Central Danube 2021-2027 (2021) highlight that development of the Paks NPP is a national task, but it has a significant impact on the region's development, particularly through the labour market and business development. Among the development priorities is the utilization of opportunities generated by the Paks NPP, both in the field of economic and human resource development. The primary objective of the regional development concept and strategic program is for the assessment area to become a "green zone," where sustainable and innovative solutions and developments dominate in every sector, taking into account the dynamic energy industry, innovative solutions, and unique natural and cultural values.
- According to the Integrated Settlement Development Strategy of Paks (ITS) Volume I-II. (2014) (Terra Stúdió 2014), based on the situation analysis and evaluation, the Paks city's economy is fundamentally determined by the NPP, which is consequently highly unipolar, and this will become even more pronounced with its expansion in the future. It also discusses the role of the NPP in various aspects of the settlement's life, such as education, culture, tourism, healthcare, and sports. The ITS emphasizes that a solid partnership has

developed between the nuclear power station and the city over the past decades. The strategic development goals outlined build in many respects on the Paks NPP and, in particular, on the expected economic and social impacts of the establishment of the Paks II NPP.

2.1.2.3. Other existing and planned nuclear facilities in the Paks site

The Interim Spent Fuel Storage (SFISF), owned by the PURAM, is located in the area registered under plot number 8803/2 and directly adjacent to the operational area of the Paks NPP, to the south-west of it. To the north of the area of Paks NPP Units 1-4, the area registered under plot number 8803/16 and directly adjacent to it is the area designated for the location of the Paks II NPP Units 5-6 constructed by the Paks II. Atomerőmű Zrt.

2.1.2.3.1. Interim storage of spent fuel

The current strategy for managing spent fuel of Paks NPP is to place spent fuel in an interim storage facility for a longer period of time, until a decision is made on its recycling, or disposal. After the spent fuel is removed from the NPP reactor, it is placed in the so-called spent fuel pool located in the NPP for a period of 3-5 years. At the end of the prescribed fallowing period, the spent fuel is transferred from the NPP to the SFISF (*Figure 2.1.2.3.1-1.)* For the transfer, the spent fuel – up to 30 pieces at a time – are placed in a transport container filled with water in the NPP. The container is transported to the interim storage facility via a trainset in a railway freight wagon with superstructure designed for this purpose.



Source: Webpage of PURAM (www.rhk.hu)

Figure 2.1.2.3.1-1. Main buildings of the SFISF and Paks NPP

The SFISF is a modular, chamber-type facility, an interim storage facility type MVDS (Modular Vault Dry Storage) of the company GEC Alstom operating on the passive cooling principle, which ensures the dry storage of spent fuel. The receiving building of the storage facility and the first storage module with three chambers were brought into service in 1997. In line with the modular design of the facility, the new four-chamber and five-chamber modules will be expanded in line with the rate of generation of spent fuel from the reactors of Paks. By 2025, a total of 28 storage chambers had been brought into service. The interim storage is currently planned to last at least 50 years.

The storage is a surface building in which the spent fuel taken from the container full of water are completely dried using a drying device, and then placed one by one in closed storage pipes by a refuelling machine. Storage pipes are lined up in chambers surrounded by reinforced concrete walls, in a vertical position. The reinforced concrete chamber around the storage pipes, which is almost 2 m thick, provides adequate shielding against radiation. Storage takes place in dry conditions and the residual heat generated is transported by a cooling system based on the natural draught effect of the air. Cooling air flows between the storage pipes and therefore does not come into direct contact with the spent fuel.

Based on the data at the end of the year 2025, 11,317 pieces of spent fuel are stored in the facility. The planned and authorized storage capacity of the storage facility has been designed taking into account the number of spent fuel generated in the first 20 years of the service life extension of the Paks NPP. Accordingly, with the construction of the storage facility with a total of 33 chambers, the storage capacity of the facility will be 17,743 spent fuels.

The interim storage of the nearly 6,144 spent fuel generated in the SSLE of 20 years is planned by PURAM in the current site of SFISF. Preparations for this, including environmental licensing, started already in 2025.

2.1.2.3.2. Commissioning of new NPP units

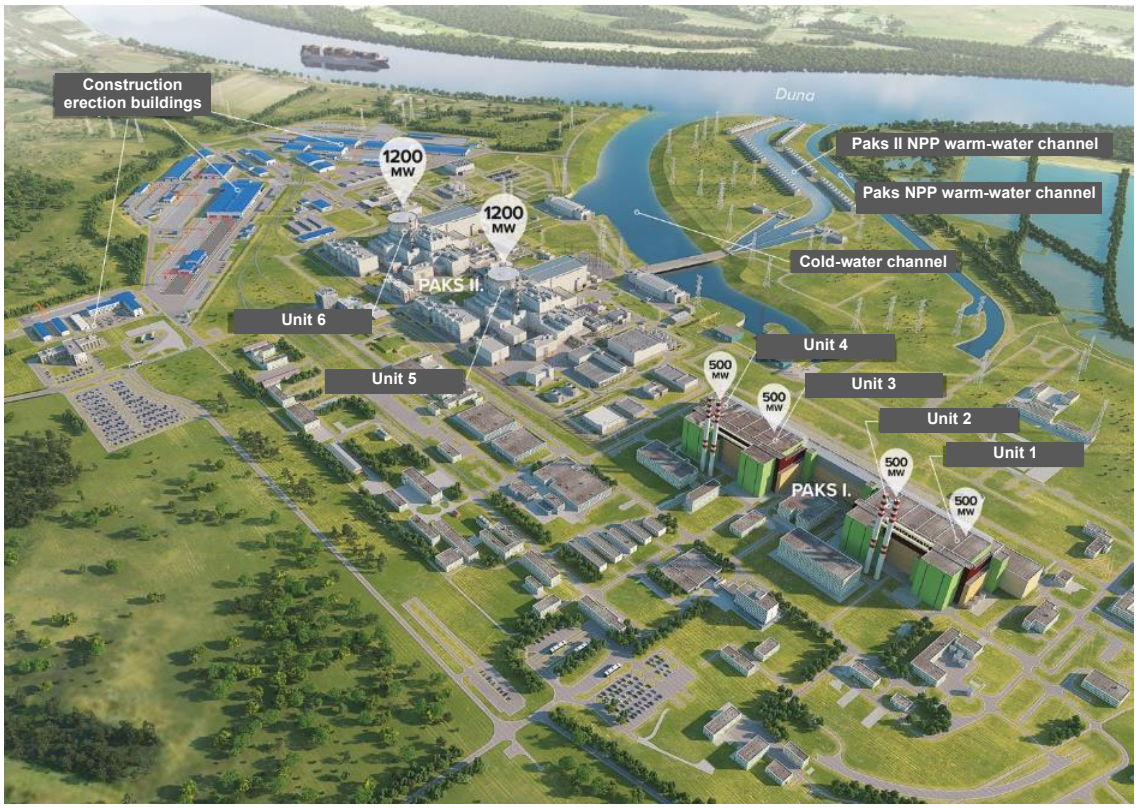
According to the Agreement between the Government of the Russian Federation and the Government of Hungary on cooperation on peaceful use of nuclear energy, two new reactor units type VVER-1200, V-527 with a nominal thermal power capacity of 3200±128 MW_{th} will be designed, built, commissioned and dismantled at the neighbouring site of the Paks NPP site.

For the two units of the Paks II NPP – similar to the Paks NPP Units 1-4 – once-through cooling from the Danube is planned to be used for the cooling of condensers. The required amount of cooling water is extracted from the cold-water channel shared with the Paks NPP by the pumps of the Paks II's own water intakes, and the warmed cooling water is returned to the river through the Paks II's own warm-water channel. The possibility to cool warmed cooling-water before returning it to the Danube is provided by a peak cooling system made up of cooling cell blocks. (Essentially the same system is planned to be implemented in the case of the Paks NPP for the period of joint operation, together with an alternative warm-water channel on the southern side of the Paks NPP's warm-water channel.)

The electricity produced in the Paks II NPP will be delivered to the national electricity system towards the new electrical substation of Biritó established to the Paks II NPP or towards the existing Paks substation at a voltage level of 400 kV. The most important technical characteristics of the Paks II NPP being currently in construction phase are as follows:

Gross electrical power:	1,262 MW_e / unit.
Net nominal output power of the unit:	1,184 MW / unit.
Nominal thermal power of the reactor:	3,200 MW / unit.
Operating range of power change:	20-100%
Maximum temperature increase in condenser cooling water:	8°C.
Cooling water use (cooling water extracted from the Danube):	132 m^3/s.
Planned lifetime:	60 years.

The visualization of the Paks II NPP with the buildings of the Paks NPP is shown in *Figure 2.1.2.3.2-1.*



Source: The webpage of Paks II NPP (www.paks2.hu)

Figure 2.1.2.3.2-1. Visualization of the Paks II NPP

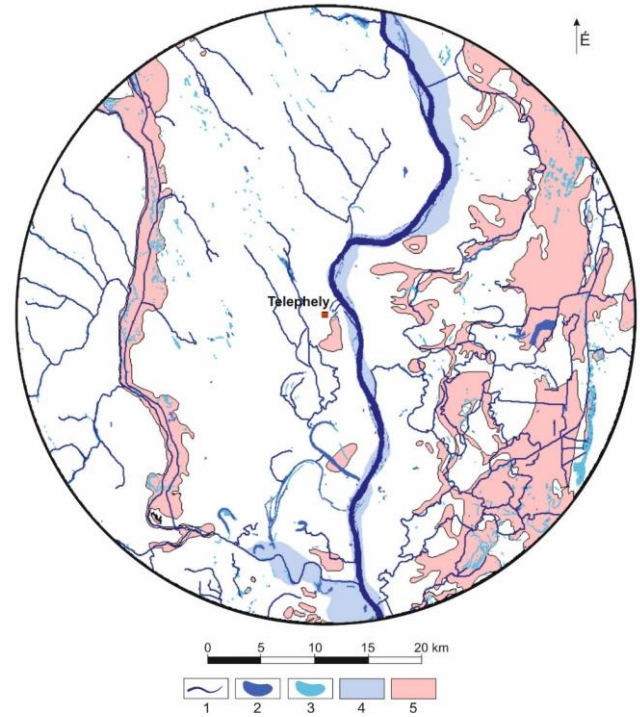
2.1.3. Hydrographic characteristics, water use

The base for hydrographic of the site area is made up of the Danube and the Sió and Sárvíz watercourses, the latter two join the Danube to the south; smaller surface water bodies are connected to these via channels from backwaters located directly on the valley floors. In the surroundings of the site, the Danube is 71 km long and, at a medium water level, covers an area of 4,287 ha with its tributaries but without backwaters, which also forms the erosion base of the area. Sió (length: 73 km, total water surface area 243 ha), Sárvíz (length: 49 km, total water surface area 86 ha), Völgységi-patak (length: 9 km) are the bigger watercourses, in addition to the Danube. In the higher areas west of the Danube, the water network is characterized by streams with small catchment areas and the larger watercourses that receive their waters. From hydrographic perspective, the large areas bordering the Danube and those to its east are characterized by former backwaters and the network of canals connecting them to one another and to the river (*Figure 2.1.3-1.).*

Based on topographic and geomorphological characteristics, a distinction can be made between the water network formed in hilly-like areas (96,780 ha) and that formed on the perfect flatland (185,963 ha). The hilly-like water network consists of streams flowing from the Mezőföld (58,767 ha), Tolnai-hegyhát, and Szekszárdi-dombság regions (the latter two covering a total of 38,013 ha), and flowing mainly into the watercourses of Sió-Sárvíz system (e.g. the Kisszékelyi-árok) and rarely into the Danube (e.g. Nagykarácsonyi-vízfolyás).

In addition to surface watercourses, there are also standing waters here, some of which are dammed lakes (e.g., Matild-tó at Nagykarácsonyi-vízfolyás), or fish ponds (e.g., on the upper section of Nagy-Gyönk-völgyi patak), and their surroundings include periodically flooded wetland and boggy and marshy areas (covering a total of 78 ha). The water network formed in the perfect flatland parts of the assessment area can basically be linked to two major units (the Danube and Sió-Sárvíz systems). On the left and right banks of the Danube, the pattern of the water network is determined exclusively by landforms resulting from changes in the river's flow direction during

the Pleistocene-Holocene period, covering a total area of 107,965 ha. In the Sió-Sárvíz system, the basic geomorphology was basically created by the two named watercourses, covering a total of 30,500 hectares. The boundary between the two areas is the region between the Southern Mezőföld and the Szekszárdi-dombság, which is at the section of the Sió between Sióagárd and Szekszárd. Here, the Sió enter the plain next to the Danube, from where a Danube backwater determines its course all the way to the mouth.



1. Surface watercourses, 2. Lakes and backwaters, 3. Marshy/boggy/waterlogged areas even during drier periods, 4. Bed at floodplain, 5. Areas regularly covered with inland water.

2.1.3 **2.1.3-1. The major surface waters of the assessment area and the associated regional characteristics**

The part of the assessment area west of the Danube is a relatively small area (47,362 ha), because it is close to the Mezőföld, and can be divided into several sections. To the north, the section between Bölcske and Paks (Madocsai-öblözet) is a perfectly flat area approximately 15 km long, with a maximum width of about 7 km. Here, the river's current main bed has moved away from the edge of the Mezőföld, and the 12.6-km-long Dunakömlődi-főcsatorna created in the former Pleistocene riverbed forms the hydrographic axis of the area unit. On the one hand, the canal collects water from streams coming from the direction of the Mezőföld. On the other hand, it carries away the waters from a 15.2 km-long network of canals created in the area between the canal and the Danube. The other area is located south of Paks, where the Danube definitively moves away from the edge of the Mezőföld, creating a perfect flatland area that widens from north to south. This area extends from Paks to the southern boundary of the assessment area, which is 33.5 km long and reaches its widest point (14 km) near Palánkpuszta. From a hydrographic perspective, in this section there is a dense network of abandoned Danube beds. These riverbed variations appear either as water-filled oxbow lakes or as canals created within the riverbed.

In the part of the assessment area east of the Danube, the current topography was shaped by the Danube's riverbed changes at the end of the Pleistocene and during the Holocene, which, from the perspective of the water network, is primarily based on the lakes formed in the former riverbeds and backwaters and the canal system connecting them; these also define the fundamental structure of the water network, which, together with the irrigation canals, forms a complete network. Here, there is a canal system totalling 1,093 km in length, which connects to the river at four points. Within the assessment area, lakes have been formed across a total of 461 ha. These are primarily oxbow lakes resulting from past changes in the Danube's riverbed.

There are marshy and boggy areas, covering a total of 1,020 ha, primarily in the surroundings of these lakes, rarely in other areas too.

The Sió-Sárvíz system's water network can be characterized by two watercourses located in the Sárvíz-völgy, which have been almost entirely canalized and run parallel to each other from north to south.

During periods of heavy rainfall and snowmelt, Danube flooding can, in extreme cases, affect an area of up to 15,133 ha. In 22 of the 75 settlements involved in the assessment belonging to the 30 km surroundings of the site, the outskirts are at risk of flooding (e.g. Paks, Dunapataj, Harta, Dunaújváros, Rácalmás, Bogyiszló etc.). In addition, inland water also appears over a larger area (51,421 ha).

There are large areas (totalling 82,860 ha) in the surroundings of the site that are under water quality protection. The largest cohesive such area covers 39,843 ha on the right bank of the Danube and 38,854 ha on the left bank. In addition to these, there are four smaller patches on the left bank, covering an area of total 846 ha, while on the right bank, areas of smaller and larger patches totalling 3,317 ha are under water quality protection.

The settlements in the wider surroundings have public drinking water networks of varying lengths, with a total length of 1,922 km. The annual volume of drinking water supplied is 9.95 million m^3. The total length of the public sewer network for wastewater drainage is 1,446 km, but in 23 settlements such service is not available (e.g. Alap, Pálfa, Kajdacs). The volume of wastewater entering the public sewer network is 6.71 million m^3 annually.

In the wider surrounding area, there are water intake points primarily used for agricultural purposes; these wells are located more, or less evenly across the area. Two, or three areas of increased density can be observed, the most pronounced of which is located in the eastern part, in the area bounded by the Duna-völgyi-főcsatorna, Büdös-tói (VII.-) csatorna and Rekettye-Bogárzó-csatorna.

Regarding water use in the future, the role of human interventions and the effects in their absence must be considered. Regarding the former, an expansion of the canal network can be assumed, but this will not significantly improve the existing standard of living. Regarding the latter, it can be concluded, that in the future, natural processes alone will not influence the course of the largely artificially defined surface river system.

2.1.4. Site-specific external man-made hazards and combinations of external hazards

An important area of meeting the nuclear safety requirements of NPPs is to demonstrate technological compliance and adequate protection against natural, and man-made hazards. For hazards of natural origin, appropriate protection against very rare events of extremely low likelihood occurring every 10,000 years shall also be justified. Consequently, during the SSLE period examined as part of the EIAR, no changes in the hazards of natural origin can be assumed that would significantly change the results and conclusions of the analyses presented in the Final Safety Analysis Report of the NPP to demonstrate compliance with the nuclear safety requirements.

The climate change during the SSLE period, which affects the NPP's environmental impacts, was nevertheless, part of the analysis of each field involved in the assessment.

Within the framework of the EIAR, two fields were thus subject to in-depth analysis beyond the aforementioned scope. On the one hand, the external man-made hazards and the combinations of external hazards as specified in *Chapter 2.1.4.*, and, on the other hand, the geological, tectonic, seismic and geotechnical characteristics of the site as specified in *Chapter 2.1.5.*

In the latter case, in this field the SSLE period from 2032 to 2057 is not compatible with the time scale of the geological and tectonic changes. The information on this field is therefore essentially for information purposes, since it is not associated with environmental impacts or only with accidents with an extremely low likelihood.

2.1.4.1. Individual man-made hazards

In order to evaluate the existing environmental conditions and the environmental impacts of the facility, the assessment of site-specific external man-made hazards examined whether possible external events related to human activity during the subsequently extended service life endanger the power plant to an extent that would have a significant impact on the power plant's surroundings.

The assessment was carried out on the basis of the available knowledge and using the information contained in the Final Safety Analysis Report (FSAR). For each hazardous activity, the assessment included an overview of the results of the site characterization of the Paks NPP and the assessments demonstrating protection against each hazard as well as an evaluation of validity over the SSLE period.

Road transport

The road transport of goods that may be hazardous to the operation of the power plant takes place on Main Road No. 6 and Motorway M6, the two main transport routes located in the surroundings of the power plant site. The units are located approximately 1,300 m from the nearest section of the Main Road No. 6, which carries the most significant road freight traffic that might affect NPP safety. During the characterization of the road transport hazard endangering the power plant, it was assessed whether the impact of a possible road transport accident (pressure wave, thermal radiation or release of toxic gases) could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening level. In nuclear safety analyses, the screening level is the threshold for the occurrence frequency of the event assessed below which the occurrence frequency of that event is so low that it is no longer necessary to consider it in the assessment. According to OAH Decree 1/2022. (IV. 29.) on nuclear safety requirements for nuclear facilities and related activities of the authorities, this screening level is 10^{-7}/year for the assessment of external man-made hazards.

On the basis of the environmental spread calculations carried out, it can be concluded that, relating to the NPP site, the impact of accidents occurring during the transport of dangerous goods on this section of the Motorway M6 is smaller than the screening criterion. A total of 6 types of dangerous goods (ammonia, chlorine, hydrochloric acid gas, hydrocarbon gas mixture (methane), gasoline, LPG) are transported on the Main Road No. 6, which may genuinely pose a hazard to the NPP site. Consequence analyses were also made for accidents assumed during the transport of these dangerous goods. Based on the results of the calculations, only the impact of an accident during the transport of chlorine exceeds the relevant screening criteria at the site. However, taking into account the protective equipment available to the main control room staff, the NPP is protected at a sufficient level against the effects of possible accidents during the transport of chlorine gas.

Water transport

The water transport of goods that may be hazardous to the operation of the NPP takes place on the Danube as a river transport route. During the characterization of the water transport hazard endangering the power plant, it was assessed whether the impact of a possible water transport accident (pressure wave, thermal radiation or hazardous substances drifting onto the site) could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening level. During the assessment, a section of the Danube in the surroundings of Paks has been identified from which the hazardous substance released into the open air may have an adverse effect on the NPP site. In the analysis, an estimated impact distance of 10 km upstream and 5 km downstream of the NPP's section was relevant (the latter applies only to gaseous substances released from ships). Based on the assessment of the consequences of the assumed accidents during water transport on the Danube section in the surroundings of the NPP, on the whole, it can be stated that there is no need to expect the occurrence of an emergency situation on the power plant site due to water transport.

Rail transport

The single-track, partly electrified railway line No. 42 of Hungarian Railways (MÁV) with a length of 40 km between Mezőfalva and Paks is the closest railway line to the NPP site. The total length of the line is 79 km (between Pusztaszabolcs and Paks), the terminus of the branch line from Mezőfalva is Paks. From the Paks terminus, a siding leads to the area of the NPP site. The NPP site can only be reached by dedicated train sets. During the characterization of the rail transport hazard endangering the power plant, it was assessed whether the impact of a possible rail transport accident (pressure wave, thermal radiation or toxic gases) could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening level.

Based on the available data, there is no shipment containing hazardous substances that arrives at the site of the NPP on a regular basis by rail, so neither the Paks NPP FSAR nor the Safety Report compiled on the basis of the Government Decree 219/2011. (X. 20.) on the protection against serious accidents related to dangerous substances establishing the NPP's disaster management permit contains an accident scenario related to rail transport. In addition to the above, for the sake of completeness, a consequence analysis was made relating to an assumed accident during, on the one hand, the handling of hazardous substances at the Paks railway station and, on the other hand, the transport of turbine oil by the special train sets. According to the analysis, no toxic substances appear at the NPP site in a concentration higher than the screening concentration in any of the meteorological conditions assessed, and the NPP is properly protected against the effects of an accident occurring during the transport of turbine oil by rail.

The transport of fresh nuclear fuel to the NPP and spent fuel to SFISF is currently carried out by rail. A special container is used for the transport, according to strict procedures and in a regulated manner, thus providing significant protection against the impact of a possible transport accident. Therefore, it can be concluded that an accident during the transport of nuclear fuel has no significant impact on the safety of units.

It should be noted that the method of fuel transit by rail may change during the duration of the SSLE. The possibility of road transport by freight vehicle directly connecting neighbouring facilities is also taken into account.

The use of airspace

Under current regulations, due to safety requirements and in accordance with Joint Decree 26/2007. (III. 1.) GKM-HM-KvVM on the designation of Hungarian airspace for air traffic purposes, the circle with a 3 km radius around the Paks NPP is a restricted airspace extending up to a flight altitude of 5,950 meters around the centre point 463443É 0185110K.

During the assessments related to airspace use, it was concluded that "nearby" airports do not currently need to be taken into account when evaluating the hazard endangering the site, due to their negligible impact; however, changes in the use of these airports must be monitored. The existing sports, private, and agricultural airfields and landing sites in the 30-50 km zone of the power plant site have been assessed both in terms of airplanes and helicopters. Considering the take-off and landing facilities and typical traffic patterns, the airfields and landing sites can be screened out based on distance; they do not pose a direct hazard to the site as long as traffic and airspace use characteristics do not change significantly, or the use and traffic of Airport Kalocsa do not change.

In characterizing the hazard of aircraft crashes at site, a statistical evaluation was conducted based on information collected regarding airspace use to determine the accident frequency per unit area (incident/year/area unit). Taking into account the calculated crash rates and assessing each aircraft category separately, it was determined that, with the exception of light aircraft and helicopters, aircraft crash hazard can be excluded from further evaluation, based on frequency.

Although light aircraft and helicopter crashes are hazardous to a lesser extent to plant safety than crashes involving larger, heavier, and faster aircraft, it was necessary to conduct a targeted evaluation of the consequences of such crashes, as the crash frequency, based on the results of the assessment, exceeds the screening threshold. According to the results of the system

engineering analysis performed, light aircraft and helicopter crashes have a negligible impact on the safety of the NPP.

Use of parking lots

During the characterization of the parking lot use hazard endangering the power plant, it was assessed whether the impact of a possible fire in the parking lot (pressure wave, thermal radiation or toxic gases), could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening level. Based on the results of the consequence analyses performed, it can be concluded that even a hypothetical accident in the parking lot belonging to power plant at the point closest to the units (opposite the office building) would not lead to consequences that endanger the safety of the NPP.

The results show that even the overpressure limit characterized by the lowest value in the calculations, which has a negligible effect, does not reach the office building of the plant. Identical conclusions can be drawn regarding the thermal radiation zones of the fireball and the pool fire. Furthermore, in the case of a fire in the parking lot, in addition to the combustion of fuel, the combustion of other vehicle spare parts (mainly tires) and the release of toxic substances and toxic combustion products generated during their combustion shall be taken into account. However, the calculations show that the impact of toxic emissions from the parking lot use does not endanger the safety of the power plant.

In the course of the assessments serving as a basis for the EIAR, the use of the parking area related to and independent of the operation of new units was assessed. As a result, it can be concluded that the establishment of parking lots significantly closer than the existing ones is not expected, and according to the results of the environmental spread calculations, there is a significant margin in the impact distance.

Use of forests

A forest fire may endanger the operation of the NPP. The forest fire possibly endangering the operation may develop on the parts of the area delimited by the operational area of the NPP (fence), the northern and southern access roads of the power plant and the Main Road No. 6, as well as on the areas south of the southern access road. During the characterization of the forest fire hazard endangering the power plant, it was assessed whether the impact of a possible forest fire (thermal radiation or toxic gases) could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening level.

On the basis of the consequence analysis and the expert evaluation carried out in the frame of the site characterization, it could be concluded that, due to the distance of the site from the surrounding forests and the nature of the fire, direct thermal radiation does not endanger the NPP units. However, it could not be excluded that smoke could spread to the site in the event of unfavourable wind direction. It could be proved by detailed analysis that the concentration of carbon monoxide in the smoke does not reach such a value on the site that the carbon monoxide can affect the ability of the staff in the main control room to act when it enters the ventilation system of the units. Analyses have shown that the direct health effects of very small solid particles formed during combustion are negligible.

Operation of industrial facilities (except Paks II NPP)

The industrial facilities involved in the assessment are, on the one hand, the industrial facilities located on the Paks NPP site but outside its technological buildings and, on the other hand, the surrounding industrial facilities as separate hazardous industrial plants, including SFISF. During the characterization of the hazard endangering the site and arising from the operation of hazardous industrial facilities, it was assessed whether the effects of a potential accident of a hazardous industrial facility (pressure wave, thermal radiation, toxic gases, flying object generated during the malfunctioning of equipment) as well as the electromagnetic and radiological effects could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening level.

During the evaluation of the hazard arising from non-nuclear accidents of the industrial facilities located on the site, a detailed assessment was carried out of the hazardous conventional industrial facilities, the storing facilities for hazardous substances, as well as the types of hazardous substances stored on the operational area and the systems for handling them. Based on the results of the propagation model calculations carried out within these assessments, it can be stated that, on the area of the power plant, apart from the release of hydrochloric acid gas in the event of an accident, there is no need to expect any emergency situation arising from the accidental release of hazardous substances handled in industrial facilities located on the NPP site, because the endangering effect of the substances involved in the assessment can be screened out on a distance basis. With the help of a subsequent consequence analysis, it was established that the NPP was also properly protected against the effects of an accident occurring when the hydrochloric acid solution was transfused.

The effects of electric, magnetic and electromagnetic fields, electromagnetic interferences and eddy currents in the ground have also been assessed and evaluated. It was found that, at the site, effects of the electric and magnetic fields and the present soil currents could not endanger the NPP. Electromagnetic fields and radiation do not interfere with devices installed in buildings as they comply with the relevant electromagnetic conformity (EMC) standards. The metal housing design of the devices, the use of high-frequency shielded cables and optical transmission ensure the expected protection level for outdoor devices.

Dangerous substances listed in Annex 1 to the Government Decree 219/2011. (X. 20.) on the protection against serious accidents, as well as the plants located in the surroundings that produce, use, store or transport dangerous substances or products containing dangerous substances were assessed.

The area involved in the assessment covered Tolna county and Bács-Kiskun county, where a total of 18 industrial objects belonging to the hazardous industrial category were identified. Of these, two facilities are operating within the 15 km radius of the NPP, that are classified as plants dealing with dangerous substances in accordance with Government Decree 219/2011. (X. 20.). One is the Vitafoam Magyarország Kft. (Industrial Park, Paks), a company producing sponges for the furniture industry, and the plant in Kalocsa of the Linzer Agro Trade Kft., a business dealing with chemical fertilizer storage.

Among the 18 hazardous plants, there are only 5 above an upper threshold value. These - except for the Szekszárdi Növény Zrt. with its 28 km distance - are located outside the 30 km radius around the NPP, between 40 and 90 km in a straight line.

Based on the activity in the hazardous plants, the substances present and their quantity, it could be determined that within the 10 km radius around the site (or also in the whole territory of the Tolna county and Bács-Kiskun county) – except for the Vitafoam Magyarország Kft. – the serious accidents that can be assumed in the plants would not have an effect exceeding the criteria applicable in the analysis within the site boundary.

According to the assessments carried out, among the effects of the possible accidents at the site of the Vitafoam Magyarország Kft., only the dispersion of toxic gases was considered to require a detailed consequence analysis. Based on the test results of the combustion of the finished product, it was found that no concentration of ERPG-2 (15 ppm) appears within the site boundary. Consequently, based on the evaluation of the severe accident scenarios for hazardous industrial facilities in the 10 km zone around the site, it can be stated that there is no risk of an emergency due to the industrial facilities located in the surroundings of the site. The assessment also found that, for the NPP, the impact of facilities located in the NPP's wider surroundings and using potentially hazardous chemical substances may also occur through transmission via transport, which is elaborated in detail in the former parts of the Chapter.

The MOL petrol filling station located in Paks, Dunaföldvári út is the closest to the site and its distance is 3.9 km from the site. The petrol filling station is not to be considered as a hazardous plant and therefore no safety analysis or safety report is available for this facility. At the same time, a detailed consequence analysis of this potential hazardous event was carried out.

The results of the analysis show that the safety of the site is not endangered by a possible accident at the petrol filling station closest to the site: neither the thermal radiation zone of the fireball nor the minimum value of the curve demonstrating the build-up of overpressure (2.0 kPa) reaches the site boundary. It can be concluded that the accident assumed at the petrol filling station closest to the site does not lead to any consequences endangering the safety of the power plant.

A high-mid-pressure steel gas pipeline between Paks and Fadd is located near the site. On the basis of environmental spread calculations using conservative values, it can be stated that the power plant site cannot be directly endangered due to leakage or breakage of the E.ON high-medium-pressure gas pipeline.

Among the surrounding industrial facilities, in terms of the hazards arising from nuclear accidents, the impact of the SFISF had to be assessed in detail. Based on the analysis carried out, there is no single event with a radiological consequence exceeding the 5 mSv limit outside the SFISF site. The evaluation of the impact on the Paks NPP found that based on the SFISF Final Safety Analysis Report, no specific accidents within the design basis can be identified that would endanger the power plant units through radiological consequences.

The NPP as a client in the relevant official licensing procedures can exercise control over what hazardous industrial plants can be installed in its surroundings.

Operation of the Paks II NPP

The man-made hazards arising from the operation of the planned new units were systematically identified, and a rigorous assessment of the probability of occurrence of the hazards and their impact on the four units being operated was carried out in order to assess the influence of the future new units operating in the immediate surroundings of the site during the extended service lifetime on the environmental impact of the facilities on the Paks NPP site. These assessments were part of the tasks carried out to support the application for construction permit for the new units.

A detailed assessment of the impact of accidents likely to occur during the handling of hazardous chemical substances on the safety of the Paks NPP was performed, including the on-site transport, storage and processing of toxic, explosive or flammable substances. The following findings could be yielded on the hazards arising from possible accidents during handling of hazardous chemical substances on the site of the new units:

- The overpressure at the Paks NPP site does not exceed the screening criterion due to a possible accident during the handling of any explosive substances, i.e. the pressure wave induced by the explosion of explosive substances can be screened out from the scope of effects endangering the safety of the Paks NPP.
- On the basis of the results of calculations carried out using a conservative method, the effects from the fire of certain containers exceed the 4 kW/m^2 screening value at the boundary of the Paks NPP site. However, further investigations have shown that neither safety-relevant buildings of the Paks NPP nor the safety-relevant systems and system components located outside the buildings are expected to be damaged as a result of thermal radiation exceeding the screening level. Overall, it can be concluded that the thermal radiation associated with a possible accident during the handling of flammable substances can be screened out from the scope of effects endangering the safety of the Paks NPP on impact basis.
- At the Paks NPP site, a pressure wave does not develop resulting in a pressure load higher than the screening value due to the potential for the release of explosive, flammable gases, vapours and aerosols, accompanied by an explosion in the event of an accident likely to occur during handling of hazardous substances. The pressure wave formed in this way can therefore be screened out from the scope of effects endangering the safety of the Paks NPP.
- In the case of atmospheric release of toxic vapours, gases and aerosols, the cloud does not reach the site of the units being operated; i.e. the toxic gas cloud formed after its release

due to a possible accident during the handling of any toxic substance can be screened out from the scope of effects endangering the safety of the Paks NPP on impact basis.

During the operation of the Paks II NPP, the mechanical destructive effects of the equipment used on the site of the new NPP may potentially endanger the Paks NPP, in the case of malfunctioning and the loss of equipment integrity, which may result in the escape of flying objects. However, on the basis of the assessments carried out, it could be concluded that all possible events during the operation of the new NPP, which could have a mechanical destructive effect due to the generation of flying objects, can be screened out from the scope of effects endangering the Paks NPP

With consideration to the quantitative and qualitative characteristics of the potentially releasing medium, an analysis was carried out regarding the impact of the failure of the systems transporting or storing liquefied media on the site of the new units and within its closed building structures on the safety of Paks NPP.

According to the assessment carried out, the impact of extreme rainfall taken into account in the design basis of the Paks NPP is significantly greater than the impact of the flooding sources of the new units. Therefore, the events resulting in flooding assumed during the operation of the new units do not endanger the safety of the Paks NPP.

Regarding the operation of the new NPP, the hazards arising from possible extreme electromagnetic effects in the event of abnormal operation have also been assessed and evaluated. It was found that the extreme electromagnetic effects assessed did not cause critical disruptions to the safety systems of the Paks NPP. In addition, the standards used by the designer ensure that due to the EMC design of the new units, only an acceptable level of disrupting effects is to be expected in the immediate surroundings of the new units.

Possible accidents in the new units can play a significant role in the hazards arising from the accidents resulting in radiological consequences of the nuclear facilities around the Paks NPP. In this context, beyond design basis accidents of the new units are the bounding events, as releases resulting from design basis accidents are below the regulatory limits defined by a sufficient degree of conservatism. Therefore, they cannot have a significant impact on either the site or the power plant units. According to requirement No. 3a.2.4.0700. of the Nuclear Safety Code (NSC) annexed to the OAH Decree 1/2022. (IV. 29.) on nuclear safety requirements for nuclear facilities and related activities of the authorities, the new units shall meet the criteria of limited (radiological) environmental impact. Therefore, in the event of complex accidents leading to the DEC1 conditions of the new units, or in the event of serious accidents leading to the DEC2 conditions so that the acceptance criteria for level 2 PSA are met, no urgent precautions should be required beyond a distance of 800 m from the unit. Although the suction inlets of the 4th unit are approximately 450 m away from the reactors of the planned new units, the nuclear accidents of the new units are not expected to require significant ancillary measures at the Paks NPP due to the limited environmental impact. In the Paks II NPP Preliminary Safety Analysis Report it is described that proven technical and administrative solutions are available to protect the Paks NPP against the expected impacts from the Paks II NPP and thus ensure the safe operation of the Paks NPP.

The Paks II NPP site being under construction is, according to Government Decree 219/2011. (X. 20.) on the protection against serious accidents, to be classified as a plant handling dangerous substances with an upper threshold value. On the basis of the Safety Report, which provides the basis for the Paks II NPP's disaster management licensing, the hazardous substances planned to be present are the following: gas oil, hydrazine hydrate, ammonium hydroxide, zinc acetate, sodium hypochlorite, hydrogen, potassium permanganate, oxygen, nitric acid, biocide, acetylene, paints (containing toluene), varnishes, heptane.

Based on a comprehensive risk assessment, structures and facilities are developed on the site of the Paks II NPP by introducing technical solutions that reduce risk. The operator will set up a well-prepared intervening organization and will have the technical safety and security locks, materials and equipment necessary to absorb, neutralize and contain the hazardous substances present on the site. In the building handling hydrazine hydrate, biocides and other substances

qualified as chemicals, built-in fire alarm and fire extinguishing equipment will be installed. In buildings where gas oil is handled, fire alarm and fire extinguishing equipment will be installed.

The room for handling hydrazine hydrate, the room for handling ammonium hydroxide, the room for handling sodium hypochlorite and the room for handling nitric acid will be equipped with an automatic fire alarm system.

Equipment for the treatment of liquid gas oil, hydrazine, ammonium hydroxide, zinc acetate, sodium hypochlorite and biocides will be equipped with a salvage device and/or a percolation water collector sump (collection recess). Technological units using flammable or explosive substances (gas oil, hydrogen, oxygen, hydrazine hydrate) will be surrounded by so-called ATEX[4] zones based on the probability of the presence of potentially explosive atmospheres, using the relevant safety regulations and equipment.

In the course of the examination of the operation of the units 5 and 6 of the Paks II NPP and the possible event sequences of deviations from normal operation presented in the safety report, it was concluded from a dedicated hazard analysis that during the use of the materials listed above, the abnormal operation of units 5 and 6 of the Paks II NPP does not affect any industrial or populated area outside the site. The assessment was carried out in accordance with the provisions of the abovementioned regulation, and the results of the assessment confirm the fulfilment of the criteria laid down therein.

Assessing the possible event sequences, it was concluded that they have no impact outside the site. Based on the full assessment, it was also determined that hydrogen and hydrazine hydrate releases are the relevant event sequences.

The risk analysis carried out for the site of Paks II NPP taking into account the surrounding population, did not show any societal risk. The analysis of the hydrazine hydrate outdoor release showed that the effect remains within the site and has a low probability of occurrence, in line with the provisions of the Government Decree 219/2011. (X. 20.). The analysis of hydrogen release at the site showed that the thermal impact and the atmospheric pressure increase are limited to the site and that the probability of occurrence of the event is low, in line with the provisions of the Decree.

With regard to the individual risk, it can be concluded that the impact calculated on the basis of the cumulative effects does not affect industrial or residential areas outside the Paks II NPP site, i.e. they are in conformity with the provisions of Government Decree 219/2011. (X. 20.).

Operation of military facilities

There are no important military facilities in the immediate surroundings of the Paks NPP. In the wider surroundings, there are two such facilities in the administrative area of Kalocsa and one in the north-east, in the area of Akasztó. During the characterization of the hazard arising from military facilities and the activities carried out therein in the surroundings of the power plant, it was assessed whether the impact of a possible accident (pressure wave, thermal radiation or spread of toxic gases) could reach the site area at a predetermined critical level affecting safety, with a frequency exceeding the screening threshold value. It was found that the hazard arising from the surrounding military facilities and activities was partly covered by transport and aircraft crash hazards. The level of exposure from the remaining hazards is negligible.

2.1.4.2. Assessment of the environmental impact of individual man-made hazards to the nuclear safety of the Paks NPP

Upon assessment of the effects of the assumed accidents occurring in the course of the activities carried out in the surroundings of the NPP and involved in the assessment, it can be stated that the power plant is properly protected from these effects and no emergency situation is to be expected as a result of these activities. On the basis of the assessments carried out, the available forecasts do not indicate any future changes that would lead to a significant change in the effects

[4] The European Directive on equipment used in potentially explosive atmospheres, which provides for the division of the plant area into zones, depending on the presence and extent of the hazard of explosion.

or accident frequencies. Consequently, the effects of accidents that may occur in the course of individual external human activities do not endanger the power plant during the planned extended service lifetime to such an extent that it would have a significant impact on the power plant's environment. Nevertheless, the site characteristics related to human activities and their changes, in view of the continuous change in the economic environment, shall continuously be monitored in the surrounding area of the NPP site during the period of the power plant service lifetime. As part of this, the hazards that may arise from certain external human activities should be periodically reviewed and reassessed in the framework of the ten-yearly periodic safety reviews, as required by the Hungarian Atomic Energy Authority. These monitoring activities are carried out in accordance with the nuclear safety requirements and permits issued for the facility.

2.1.4.3. Non-nuclear accidents with potential environmental impact during on-site activities

Non-nuclear accidents that may occur during on-site activities related to the operation of the NPP, i.e. electricity production, may also have an impact on the environment as additional man-made hazards. It was also an important objective of the assessment of external man-made hazards was to assess and evaluate, whether the environmental impact of these hazards remains negligible during the service lifetime subsequently extended. The safety report of the MVM Paksi Atomerőmű Zrt. drawn up in accordance with Government Decree 219/2011. (X. 20.) on the protection against serious accidents includes the assessment and evaluation of the hazardous activities carried out on at the Paks NPP and the presentation of the safety management system. The assessment of the non-radiological environmental impacts and environmental loads from external man-made hazards was performed on the basis of this safety report.

As part of the analysis documented in the safety report, the hazardous substances handled at the Paks NPP and in its technological buildings, including their location, quantity and possible transport routes within the site, were identified and characterized. The safety-relevant hazards, the occurrences of major-accident sequences were examined in detail, the accidents with the most serious environmental consequences were identified, and the harmful consequences of the possible escape and spread of hazardous substances were determined. Qualitative and then quantitative probabilistic analysis and evaluation of the risks associated with potential serious accidents were carried out.

Hydrazine is the only hazardous substance necessary for the operation of the power plant which, due to its quantity, is considered to be an important source of danger under the aforementioned Government Decree. In the light of all the relevant factors, it can be concluded that the hazard at Paks NPP site resulting from serious accidents involving exposure to the environment is at an acceptable level.

The plant is well-prepared to deal with this type of emergencies, including possible accidents during the handling of hydrazine hydrate. The technology of the Paks NPP is not expected to change to a degree that would materially affect the handling of hazardous substances in the power plant and would require a revision or amendment of potential emergencies. Thus, the environmental impact of these hazards remains negligible during the extended service lifetime. At the same time, the operator will continue to ensure that the level of hazard from serious environmental accidents remains reasonably low, just as the plant will always be prepared to deal with potential emergencies.

2.1.4.4. Combinations of external hazards endangering the nuclear safety of the Paks NPP

In addition to single hazards, combinations of external hazards were assessed and evaluated for completeness, with a targeted evaluation of the available assessment results.

Selection of hazard combinations

As a first step, an initial list of hazard combinations was compiled in order to select the combinations of external hazards that required detailed analysis. Use was made of the relevant

national and international regulatory requirements and recommendations, standards and guidelines for probabilistic safety analyses, as well as relevant international practices to develop a list of possible individual external hazards the aim of being comprehensive. Although the identification of hazard combinations should be based on a complete list of individual hazards, it is possible to exclude several hazards from the scope of the assessment based on relevance or frequency before hazard combinations are formed. The list of 37 individual hazards used to compile the hazard combinations was as follows:

- vibratory ground motion caused by an earthquake,
- soil liquefaction,
- flash flood,
- flooding due to sudden snow melt,
- flooding (flood),
- high groundwater level
- flooding / low water level due to obstruction of upstream or downstream river channels,
- flooding resulting from damage to upstream and downstream facilities,
- precipitation,
- snow,
- extremely high temperature,
- extremely low temperature,
- high cooling water temperature,
- high humidity,
- low river level due to drought,
- icing,
- hail,
- lightning,
- high wind, storm,
- tornado,
- water surface ice,
- ice barriers,
- mist, fog,
- Danube contamination endangering the water intake,
- forest fire,
- explosion during industrial activity,
- release of hazardous chemical substances during industrial activity,
- the discharge of a solid or liquid substance into a river during transport by river,
- explosion resulting from transport,
- release of hazardous chemical substances during transport,
- explosion during pipeline transport,
- release of hazardous chemical substances during pipeline transport,
- aircraft crash (overflights),
- instability of the electrical grid,
- electromagnetic interference,
- high voltage eddy current,
- fire caused by human activity.

In line with the international best practices, the compilation and use of a so-called cross-correlation table helped to identify hazard combinations that should actually be examined for the Paks NPP, using the external hazards pre-screened on the basis of relevance and frequency.

Screening of hazard combinations

Event or phenomenon combinations included in the relevant list of hazard combinations were subjected to multi-stage screening, with the following breakdown of hazard groups:

- hydrological hazards,
- external hazards arising from human activities,
- Danube contamination affecting the availability of the cooling water,
- hazards related to relevant areas of earth science,
- meteorological hazards.

Based on the screening of hazard combinations, a detailed assessment of the following combinations was found necessary:

- external hazards arising from human activities under extreme meteorological conditions,
- strong wind and precipitation and lightning (storm),
- strong wind and snow,
- extremely high air temperature and high cooling water temperature,
- extremely low air temperature and water surface ice (and icing and snow),
- simultaneous accidents in several industrial facilities (e.g. due to earthquakes),
- joint occurrence of earthquakes and extremely high or low air temperature,

- combinations of hydrological hazards,
- combinations of potential hazards in the field of geosciences.

Determination of load values at the design basis level

Meteorological conditions have a significant impact on the effects of fire and the release of toxic gases. Further assessment was carried out to determine whether a possible accident during the handling of hazardous substances can have a significant impact on the safety of the power plant with a frequency exceeding the screening level, under extreme meteorological conditions. Based on the results of the analysis, accidents that may occur during the handling of hazardous substances under reasonably foreseeable extreme weather conditions do not have a greater impact on the safety of the NPP than under the originally considered non-extreme weather conditions.

Due to the combination of earthquake and strong wind, accidents leading to the release of hazardous substances may occur simultaneously in several neighbouring industrial facilities. Further studies were carried out to determine whether such accidents could have a significant impact on the safety of the power plant with a frequency exceeding the screening level. According to the analyses results, due to the presumed locations and distances of accidents and the different effects of various types of sources, the threat on the NPP does not change if accidents occur in several facilities at the same time.

In the case of combinations of extremely high or extremely low temperatures and earthquakes, storms and snow accumulation and strong winds, the load value pairs for hazard combinations to be considered in the design basis, i.e. with a frequency of 10^{-4}/year, were defined. The snowstorm could be described as the relative frequency of strong winds during intense snowfalls. Extreme warm as well as cold weather are characterized by consistent values of loads (air temperature and cooling water temperature) taken into account in the design basis.

Evaluation of the power plant protection against design basis loads

Failures or event sequences resulting from earthquakes, extreme warm or cold weather as individual hazards outweigh (bound) the event sequences resulting from the joint occurrence of their effects, since significant failures are expected only due to hazards causing a higher load than the individual hazards considered in the design basis, and the frequency of exceeding the joint occurrence is by orders of magnitudes lower than that of the individual hazards. An exception is the accident sequence in which a moderately large earthquake, accompanied by moderately extreme temperatures, causes the failure of the cooling or heating system of the power plant, since in this case there is the possibility of significant damage at loads lower than the ones resulting from the individual hazards included in the design basis. The combined effects of an earthquake and extreme warm or cold weather on the plant were assessed in detail. It was concluded that the power plant is protected against the effects of an earthquake occurring during extremely warm weather included in the design basis, and the corresponding safety margin is so significant that the effects of the extreme heat and earthquake would not endanger the power plant to such an extent that it would have a significant impact on the power plant environment even during the extended service lifetime.

In the case of failures or event sequences resulting from extreme precipitation, extreme wind loads and lightning as individual hazards, those accident sequences were selected for further assessment in which extreme precipitation is accompanied by high winds or lightning, leading to the loss of the external electrical grid. The rationale for selection is the fact that in this case it is necessary to operate the diesel generators, the cooling water of which also enters the southern canal through the rainwater drainage system, imposing further loads on the rainwater drainage system. In 2017, two relief lines were installed in the surroundings of the diesel generator building of units 3 and 4. Following this plant modification, the rainwater drainage network is able to properly drain the amount of rainfall included in the design basis, and even the quantity of the precipitation with a frequency of 10^{-7}/year, together with the water generated during the operation of one diesel generator per unit. Consequently, the power plant is protected against the effects of storm as a hazard combination included in the design basis with such a significant margin that

the effects of the storm do not endanger the power plant even during the extended service lifetime to such an extent that it would have a significant impact on the power plant environment.

Based on the previously performed strength calculations for verification purposes and the detailed assessments of single hazards, it was concluded that the vulnerability of power plant buildings to the combination of wind and snow is covered by the vulnerability to individual loads. Consequently, the safety-relevant buildings of the power plant can be considered protected against the load combinations included in the design basis, and they remain protected until the end of the extended service lifetime if the protection against individual hazards is maintained. A detailed assessment has been carried out to determine whether the air intake structures of the diesel generator rooms and the main building ventilations can be clogged by strong winds during intense snowfall. According to the power plant experts, due to the large storage capacity and immediate snow removal, the vents are not expected to become clogged with snow. Furthermore, the diesel generators can be operated indefinitely with internal air intake. Consequently, the safety-related ventilation systems and the diesel generators can be considered protected against the load combinations included in the design basis, and the effects of the snowstorm do not endanger the power plant in the service lifetime subsequently extended to such an extent that it would have a meaningful impact on the environment of the power plant.

The plant response to extreme warm and extreme cold weather can be adequately characterized by the findings of the assessment of the response to the hazards included in these hazard combinations, since, for example, the temperature of the Danube water was taken into account in the assessment of extreme heat. Consequently, there is no reason to assess these hazards as combinations of hazards.

2.1.5. Geological, tectonic, seismic and geotechnical characteristics of the site

Due to the selection of the Paks site for the construction of a NPP, the Paks area is the most thoroughly explored and studied in Hungary. Geoscientific investigations of the Paks site, along with related scientific research aimed at understanding the geology of the Pannonian Basin, have been ongoing for six decades. Targeted research conducted at the site and related academic studies have made it possible to understand the site's complex geological, seismotectonic and geotechnical characteristics and to evaluate them in accordance with nuclear safety requirements. On that basis, the design and safety analysis of the three nuclear facilities at the site (Paks NPP, Interim Spent Fuel Storage and Paks II NPP) were carried out, as well as the safety of the oldest NPP was significantly enhanced, and these were approved by the regulatory authorities. Both of the listed facilities being operated, as well as the two new power plant units currently under construction comply with the geological, tectonic, seismic and geotechnical requirements applicable to the respective facility as prescribed in the Nuclear Safety Code.

The Paks site has complex seismotectonic characteristics. The existence of the fault system at and around the site was known well before the site was selected. At the same time, the activity of the fault system, which was a crucial issue in determining the site's seismicity, was a matter of debate. There was no direct empirical evidence of fault activity; the Quaternary reactivation of the faults was indicated only by the earthquake of Kecskemét in 1911.

A central focus in planning the site investigation program of the Paks II project was the precise mapping of the fault system, the examination of morphological and paleoseismic indicators of Quaternary activity, along with highly detailed geophysical, microseismic, and space geodetic motion studies. The Geological Research Program conducted in connection with the Paks II NPP site investigation confirmed the Quaternary reactivation of the mapped Dunaszentgyörgy-Harta structure. At the same time, it also established that an earthquake of such magnitude as to cause a permanent lateral surface displacement significant from the perspective of nuclear safety is not conceivable on this fault system.

2.1.5.1. Geological-tectonic characterization of the Paks site surroundings

Six major geological horizons can be distinguished in the area, which demarcate significant developmental and facies units from one another:

a) Pre-Cenozoic basement.
b) Lower-Middle Miocene geological horizon.
c) Erosional depositional surface of Pannonian formations.
d) Concordant depositional surface of the Algyő Formation.
e) Boundary between the Algyő Formation and the overlying Újfalu and Zagyva Formations.
f) Erosional base level surface of discordance of Quaternary formations.

The surfaces were defined based on geophysical and drilling data for the area. The concept of the base level surface of Quaternary formations was developed through the evaluation and software modelling of stratigraphic sequences from 1,329 boreholes. The evolutionary history can be clearly divided into the following phases:

a) Pre-Miocene developmental stage.
b) Early and Middle Miocene developmental stage.
c) Late Miocene-Pliocene developmental stage.

The area was characterized by moderate subsidence during the Pannonian period; consequently, the turbidite-derived formations (Szolnok Formation) that formed in the deep basin upstream of the delta are absent above the Endrőd Formation. So, the layers of the Algyő Formation follow directly on top of the Endrőd Formation.

The defining structural feature of the area is the “Kapos Line”, which can be traced for approximately 100 km in the pre-Cenozoic basement and runs in an ENE-WSW direction. Using the results of fault mapping, a total of 41 geologically and geometrically consistent 3D numerical fault surfaces were identified in the field of research, some of which do not reach the Pannonian-Quaternary boundary. The mapping of these faults provided precise data regarding their geometry and style. The Dunaszentgyörgy-Harta fault zone, which branches off from the Kapos Line in a north-easterly direction at Dunaszentgyörgy and passes beneath the site, plays a decisive role; together with the eastern section of the Kapos Line, it constitutes a lateral displacement structural element indicating neotectonic activity in the area.

The activity of these faults has been the subject of scientific debate for nearly a century, which also determined the main direction of investigations following 2011. This will be described in detail when presenting the results of the paleoseismic studies.

2.1.5.2. Seismicity of the site and its surroundings

Earthquake activity in Hungary is fairly diffuse and can be characterized as intraplate seismicity. The relationship $\log N = 5.84\text{-}1.07\ M_w$ holds true for the entire Carpathian-Pannonian region (44°-50° N, 13°-28° E), where N is the annual number of earthquakes above a given magnitude. This means that earthquakes of $M_W \geq 6$ occur every 3.8 years across the entire region; earthquakes of $M_W \geq 5$ occur three times a year; and earthquakes of $M_W \geq 4$ occur on average thirty-six times a year.

The activity of the site and its surroundings is very low as it is typical for the central part of the Pannonian Basin. Earthquakes often cannot be clearly linked to tectonic structures, as the uncertainty of seismotectonic and geological knowledge makes it impossible to determine which fault caused which earthquake.

Earthquakes in Hungary and in the surroundings of Paks have been monitored by a highly sensitive seismic network since 1995. Taking into account, that the detection capability of the monitoring network is focusing on Paks, it can be stated with a high degree of certainty that during the three-decade observation period, there was no earthquake in the immediate surroundings of Paks whose magnitude reached the value of $M_L = 1.0$. Therefore, recent activity in the local structures can be ruled out with increasing probability; it means that no seismically active fault

can be identified in the surroundings of Paks. Nor do any faults identified or hypothesized near the site based on other geophysical, geological, and geomorphological observations exhibit seismic activity in the 0.75-1 magnitude range.

Thanks to microseismic monitoring in Paks that began in 1995 and the new borehole seismograph stations established in 2016 as part of the Paks II NPP Geological Research Program, 6,002 small- and medium-magnitude earthquakes were recorded in Hungary and its surroundings (45,5°-49,0° N, 16,0°-23,0° E) between 1995 and 2024. The earthquakes ranged in magnitude from –0.8 to 5.7. Of these, 1,082 had their epicentres within 100-km radius surroundings of the site.

A total of 4,071 earthquakes is known from historical sources for the period between 456 and 1994. Thus, the majority of the Hungarian earthquake catalogues now consists of instrumentally recorded events, whose epicentres and depths are known with an order of magnitude greater precision than those of historical earthquakes.

As a result of monitoring, the Gutenberg-Richter relationship regarding earthquake frequency – which is the most important input data for seismic hazard calculations – has become significantly more reliable. In the surroundings of Paks, the density of earthquake frequency is lower than the national average, at one-quarter to one-fifth of it.

Since the microseismological monitoring, after the completion of the Paks II NPP Geological Research Program, the last comprehensive seismological analysis, has identified 563 minor earthquakes within 100-km radius surroundings of Paks site between 2017 and 2024. Of these, 36 occurred within 50 km of the site, and 3 within 30 km. The closest event was 22 km from the site and had a magnitude of 1.9.

2.1.5.3. Geodynamic monitoring results

Results obtained using the GNSS (Global Navigation Satellite System) method of space geodesy for the past twenty-five years show that local, relative current horizontal crustal movement rates in the surroundings of the Paks site are below 0.5 mm/year. Larger-scale space geodetic crustal movement studies, assuming a uniform, diffuse deformation distribution, indicate N-S and E-W compression at a rate of 0.2-0.4 mm/year in the same area. Vertical surface movements in the area are below the 1 mm/year error threshold. There are only one or two exceptions to this, where the observed movement is of transient, compaction, or technogenic origin.

GPS data also clearly show that there is no significant current lateral displacement along the faults mapped in the area; the two tectonic units essentially do not move relative to each other, or this movement is below the 0.1 mm/year level.

2.1.5.4. The results of the paleoseismic studies

The faults in the surroundings of the site were mapped using 2D and 3D seismic tests. The surface and near-surface manifestations of faults reaching Quaternary strata can best be explored through trenching. The trenches established during the Paks II NPP Geological Research Program were prepared using high-resolution geophysical tests and shallow drillings. The plastic deformation structures uncovered in the site and in the surroundings of the site (Motorway M6 cutting, harbour quay) demonstrated Late Pleistocene activity, which served as confirmation of the presumed or expected results for the evaluators.

A detailed review of the excavations conducted in the site and its surroundings and a critical review of the interpretation provided in the Geological Research Program, and a scientific characterization of the paleoseismic signs was carried out in 2020. It was hypothesized that the deformations caused by soil liquefaction observed in the loose sediment were the result of earthquakes with a magnitude of at least 5, which, based on dating, occurred at intervals of approximately one thousand years during the Late Pleistocene, 20,000 years ago in the Dunaszentgyörgy-Harta fault zone. Local deformations or dilations of the sand layers measuring a few centimetres in the immediate surroundings of the fractures do not indicate any horizontal or vertical slippage of the sand bodies on either side of the fracture relative to one another. This can

be explained by the fact that in the bedrock and older Cenozoic rocks, any clear displacement is absorbed by the loose sediments near the surface, so the surface is no longer noticeably deformed. Most of the observable clefts are likely not direct extensions of fault branches reaching the surface, but rather expansion clefts or compression fissures formed indirectly by the effects of seismic waves.

This assessment was reviewed based on the document marked IAEA TECDOC-1767 with the title of “The contribution of palaeoseismology to seismic hazard assessment in site evaluation for nuclear installations” as standard methodological guidelines to obtain data for the analysis of surface displacement risk.

The key findings of the analysis can be summarized as follows. The identified deformations can be defined as “environmental effects of earthquakes,” (according to TECDOC-1767: Earthquake Environmental Effect – EEE), which confirm Late Pleistocene activity. The age determination can be considered appropriate, but based on the environmental effects of the earthquakes, the fault can only be localized with a very large margin of error, if at all. The assumption that the features observed in the test trenches are the result of fault activity beneath the trench is logical but not exclusive, since the condition for soil liquefaction causing water outflow is not the presence of a fault beneath it, but rather that the soil has a water-saturated, cohesionless granular structure that is affected by earthquake-induced land movement. The estimation of the minimum magnitude of $M_W \geq 5$ did not take into account that, according to the latest research, Late Pleistocene paleosol formation could have occurred even in the event of an earthquake with a magnitude of $M_W \gtrsim 4$.

2.1.5.5. Determination of the earthquake hazard using the probabilistic method

The analysis of seismic hazard by probabilistic method is based on models of seismotectonic/seismogenic zones. In the first such analysis conducted in the 1990s the faults in the surroundings of the site were also modelled. However, very little weight assigned to the uncertain fault activity. At that time the highly respected scientists invited by the IAEA classified the faults as inactive. The three seismogenic zone models forming the basis of the analysis were developed based on a knowledge base that has been growing for more than 30 years now. Similarly, the attenuation equations were selected based on decades of experience, and the most advanced software currently available was used for the logic tree analysis, which has three key outputs: the conditional bedrock hazard curve, the response spectrum (Uniform Hazard Response Spectrum – UHRS), and the hazard deaggregation.

Surface characteristics were calculated using a method that accounts for the nonlinear behaviour of young strata, based on the refined soil model. With regard to the maximum horizontal acceleration with a return period of 10^{-4}/year, the results obtained over the past thirty years using various models and software were essentially identical, lead to result showing no significant deviation.

A difference compared to previous analyses was identified with regard to the response spectrum of the vertical component. This is because the vertical component was calculated in accordance with the latest scientific findings and taking into account the specific characteristics of the site.

During the update of the Paks NPP Final Safety Analysis Report, which took into account the lessons learned and results of the Paks II NPP Geological Research Program in 2021, it was confirmed that the previously obtained seismic hazard results are consistent with earlier analyses regarding both bedrock and surface horizontal UHRS, and the discrepancies were manageable when accounting for the input incoherence affecting the base plate of the structures.

2.1.5.6. Geotechnical characterization – soil liquefaction hazard analysis

Significant supplementary on-site geotechnical investigations were conducted at the Paks NPP site in 2014, primarily to investigate soil liquefaction and ground subsidence. An extensive engineering geology program carried out on the new units provided useful supplementary information for this purpose. Reviewing the results of the latter, it can be concluded

that these new data do not have a significant impact on the validity of the statistical soil model built on the existing data; rather, they confirm it and are consistent with it.

The assessment of the potential for global soil liquefaction was performed at a probability level corresponding to the design earthquake (10^{-4}/year), using the stress-based empirical method most commonly used in engineering seismology, as well as the effective stress method that accounts for the increase and dissipation of pore water pressure, applied to the average stratigraphic sequence and average groundwater level representative of the site.

The results obtained confirmed that, at a 10^{-4}/year probability level, global soil liquefaction affecting the entire stratigraphic sequence is not to be expected. An analysis of the local occurrence of soil liquefaction, lateral variability, and ground surface subsidence caused by liquefaction indicates that, at the probability level of 10^{-4}/year corresponding to the design earthquake, the greatest subsidence is expected at the NW corner of the reactor building of the units 3-4, with a magnitude of 5.08 cm according to a conservative estimate. The evaluations carried out in 2021 taking into account the findings and results of the Geological Research Program also confirmed that the results regarding soil liquefaction are consistent with previous analyses.

2.1.5.7. Surface displacement risks caused by faults in the site and its surroundings

A detailed analysis of faults in the site and its surroundings classified as active in the Quaternary period aimed to answer the question of whether an earthquake of such magnitude could occur on the fault that displacement along the fault would also appear at the surface. For a fault that manifests at the surface, its hazard curve must be determined, based on which it can be decided whether, given the magnitude and/or frequency of the displacement, it endangers the nuclear safety or is irrelevant, because a displacement of significant magnitude endangering the nuclear safety either does not occur, or occurs with a negligible annual frequency.

The screening is based on the principle of “practical elimination” (see documents: 20. requirements on planning of IAEA SSR-2/1, and WENRA „Report – Practical Elimination Applied to New NPP Designs – Key Elements and Expectations” 2019). Such an event or scenario can be considered practically impossible if it cannot physically occur (if there is no volcano, there is no volcanic eruption), or if the probability of a large/early release occurring as a result of the event is extremely low (10^{-6}/year – 10^{-7}/year), which can be demonstrated with a high degree of confidence.

It is important to mention that Quarter-period activity, which may manifest itself as surface displacement, is not the same as “capability”, a concept that is essential for assessing nuclear safety. Capability refers to the potential of a fault to generate a surface displacement that could affect nuclear safety. In other words, if a displacement along the fault could manifest on the surface, could it cause effects that could endanger safety functions. The displacement is considered significant if this is possible. Determining this is a matter of expertise for safety analysis and designers of the NPP, particularly rather structural designers and civil engineers.

Even without any analysis, as a general rule, it can be stated that the displacement of 10 cm can be classified as negligible from a nuclear safety perspective. However, as an example specific to the new units in Paks, for the buildings on the nuclear island – where the tilt angle not limiting normal operation is 1/1,000 – a disparity of approximately 0.1 m is permitted in terms of the typical size of the foundation slab, while three times this value, 0.3 m, is allowed as an extraordinary effect. According to the standards for reinforced concrete buildings, e.g. EUROCODE 7), cracks shall be calculated at a relative displacement of magnitude 1/300.

To assess the effect of surface displacement along the fault endangering the nuclear safety, the surface displacement hazard curve shall be determined, and, based on the frequency of displacement, it shall be determined whether the displacement could cause a loss of security function that violates the probability limits for zone melting and large/early releases of the nuclear safety requirements.

IAEA SSR-1 and SSG-9 (Rev.1.) defines the concept of “capability” specifying three attributes: (a) there have been earthquakes that repeatedly caused significant surface displacement

(significance should be understood in terms of magnitude and frequency as they relate to nuclear safety, not in a neotectonic sense); (b) there is a structural connection to a fault causing surface displacement; (c) an earthquake of sufficient magnitude to cause surface displacement may occur on the fault. If any of these conditions is true, the fault is capable, but this does not automatically mean that it is relevant from a nuclear safety perspective.

A preliminary screening can be performed based on the maximum possible magnitude characteristic of the fault. There is no specific data for this; trenching suggests a value of approximately between M_W 4 and 5. Indirectly, the maximum magnitude can be estimated from the length of the faults or from the maximum size of the rupture, which is determined by the fault length and the thickness of the seismogenic layer. Based on available empirical correlations, as well as data from probabilistic earthquake hazard analysis and those from source regions including the site, the maximum magnitude is likely between 5.9 and 6.7. Consequently, the probability of surface displacement – depending on the empirical formula used – ranges from 0.1 to 0.8. The question is, with what annual frequency might an earthquake with a magnitude e.g. 6.7 occur. Based on the magnitude-frequency curve considered, this ranges between 10^{-7}/year and 10^{-8}/year. If the requirement for a large/early release is 10^{-5}/year cumulative for the existing power plant (requirement under point 3.2.4.0900. of Nuclear Safety Code[5]), it means, 10^{-6}/year for a single event, then the hazard can already be screened based on this criterion.

If Quaternary activity indicates, according to the possibility of surface displacement, the requirement specified in IAEA SSR-1 and IAEA guideline SSG-9 (Rev. 1), a probabilistic surface displacement hazard analysis is required to decide whether the hazard is relevant from a nuclear safety perspective. This is based on characterizing the activity of the specific fault/faults using a magnitude-frequency curve. The available data is insufficient for this, and even if extensive research were initiated taking into account the seismicity and geodynamic characteristics of the site, sufficient data would hardly be generated for this purpose, particularly given that lateral displacement along the fault in loose sediment, within a saturated loose overburden prone to liquefaction, would only be observable in the event of extremely large earthquakes.

Classical probabilistic surface displacement hazard analysis methods (Probabilistic Fault Displacement Hazard Analysis – PFDHA) cannot be applied to these faults due to the lack of a magnitude-frequency relationship applicable to them. The amount of paleoseismic data is insufficient for this purpose, nor is it suitable for accurately determining magnitude, and historical and instrumental earthquake records do not at all confirm the activity of these faults. Following the concept of the PFDHA method, the hazard curve for surface displacement risk can be derived using multiple approaches based on the results of probabilistic earthquake hazard analysis (Probabilistic Seismic Hazard Assessment – PSHA). Based on the hazard curve, the risk of permanent surface displacement is practically negligible, not even significant at the frequency of 10^{-7}/year, and the phenomenon of cliff edge can also be excluded.

2.1.6. Hydrogeological characteristic of the site

Concerning the groundwater area, it can be said that the watertight bed of the groundwater storage complex is formed by a Pannonian lake clay formation, which is settled at a depth of 30-40 m below the current terrain level and is usually eroded by river water erosion. In some places, however, older Pleistocene layers can be found, which are of Eolic origin and their transformed versions.

For groundwater storage and drainage, the most important is the New-Pleistocene river sediment, which was formed in a young sink stretching from Paks to Sió mouth, with a regional extent and a thickness of about 20 m. The lower section of the layer is 10-15 m thick, poorly classified, pebbly sandstone, gravel sand, but sometimes wedged sand levels also can be found in it. This is the best drainage structure in the region, which determines the movement and reservoir of groundwater. The upper 5-10 m section of the New-Pleistocene river sediment is presumably

[5] Annexes to the OAH Decree 1/2022. (IV. 29.) on Nuclear Safety Requirements for Nuclear Facilities and Related Activities of the Authorities.

sediment from flooding, fine sandy scattered gravel. This layer is directly related to the Danube's bed, in which the current medium- and small-waterbed of the Danube was formed.

On the Pleistocene aquifers holocene layers were settled, the thickness of which is 5-10 m. In the 1-3 km band bordering the Danube, the New-Holocene sediments of the Danube form the lid, their material is river gravel, sand, casting sludge, casting clay, loess sludge. Further afield, the quicksand cover from the Danube sediment forms the upper level, which sometimes contains covered fossil soil layers.

From among the morphological forms in the wind-blown areas, in the 6-8 m thick semi-bonded sand hills, the wind groove and the residual ridge can be recognized. Despite its Eolic origin, its material is relatively poorly classified, and due to its good leakage factor, it allows a significant part of the precipitation fallen to the surface to infiltrate the soil. A high loess level (160-180 mBSl) stretches towards NW from the power plant to NNW. The younger upper sections of the loess are loose settlements; due to their large gap volume they are relatively good at water drainage. This allows the drainage of the infiltrated rainwater into the depths. At the boundary of the adobe levels (clay), water flows towards the erosion base (Danube).

The hydrogeological structure described is modified by two factors:

1. The Danube' bank lane is enmeshed by loaded former meanders, which significantly alter the overall geological picture and can also influence flow conditions.
2. Due to the building of the area, the original morphological and soil conditions have changed significantly, the original space level is covered with filling from 0-7 m thick local material. The building can also modify the flow of groundwater in the surroundings of deep foundation structures and subsurface facilities. However, these changes take place only in the immediate surroundings of the facilities and do not have an impact on a larger area.

The groundwater leakages in the porous sandy-gravel complex of the Quaternary period (Upper Pleistocene, Holocene) in the direction of the living water flow of Danube draining it. Groundwater leakage can be divided into three characteristic zones based on the characteristics and direction of the leakage.

The first zone, the direction of leakage of which is steady, points in the direction of the living water flow of Danube. It does not change direction, the value of the hydraulic gradient changes slightly. It has a direct leak-hydraulic relationship with the background groundwater fed by rainwater infiltrated in the Mezőföld area.

The second zone, the transitional or stagnant zone, whose characteristic leakage direction continues to point in the direction of the Danube draining it, while the hydraulic gradient of the groundwater is significantly reduced, and in certain leak-hydraulic situations its value will be 0.

The third zone is the zone of the Danube effect area, where the characteristic leakage direction of groundwater can be bidirectional, which is influenced by the current river water level. During a high and sustained flooding, the leak direction of the groundwater points towards the background, during this period the pressure level of the groundwater rises. During the long-lasting medium and small water periods of the Danube, the leakage direction of the groundwater changes and points towards the draining direction of the living water stream of Danube. During this period, the pressure level of the groundwater decreases.

The direction of the groundwater flow and the speed of the flow are primarily important for contaminations entering the soil, as any contamination possible being present can be traced in the knowledge of the flow. As a result of calamity events, some of the contamination entering the soil in liquid form sticks to the surface of the soil particles, while the other part, after a vertical leakage, reaches the current level of groundwater, dissipates, mixes with the groundwater and moves with it. The speed of movement is specific and varies depending on the type of contaminant.

The assessment area can be divided into two characteristic zones, the background area and the strip along the surface watercourse of Danube. There is a transition zone between them. The groundwater around the power plant and its surroundings is fed from the western side – from the higher space level in Paks-Mezőföld – by the horizontal leakage of groundwater.

The direction of groundwater flow in the assessment area is determined by two main factors. One is the water level of the Danube; the other is the precipitation through the infiltration from the background. The water level of the Danube can change the level and flow direction of the groundwater in both directions. The groundwater drainage effect of the Danube is to a lesser extent present in the background, so that a larger amount of groundwater remains in the aquifer on the background area.

Typical groundwater flow direction is W-E, which changes locally, in the surroundings of the cold-water channel entering also the power plant area, to SW-NE, and perpendicular to the canal bank. The average hydraulic gradient in the area is 2.5-3 m/km. At low and medium level of Danube water, the drainage effect of the river prevails, while, at high water level, it re-swells the groundwater. Thus, in the groundwater level detection wells, the water level changes according to the flow regime of the Danube, but this effect is continuously weakened as it moves away from the river. The rate of transmission of pressure waves in groundwater caused by flooding is ~100 m/day.

The groundwater levels measured in the monitoring wells follow well the Danube's water level changes and the withdrawal of floodings. Their effects are felt in a band of about 1 km from the Danube's line, and as they move away from it, their effects are significantly reduced and shifted in time.

2.1.7. Hydromorphological characteristics of the site

The River Danube is the dominant watercourse in the immediate surroundings of Paks NPP and also in the wider region. The water supply of the NPP is provided through a cold-water channel branching out of the Danube at 1,526.6 rkm. The warmed-up water is channelled back into the main bed through the warm-water channel.

On the river section between Dunaföldvár and the national border, the average width of the medium-water channel is 400-600 m, at the NPP (1,527 rkm) 430 m, and the bed width is 1.1-1.2 km. On the basis of the regulatory plans drawn up at the end of the 1970s, the river section between the Dunaföldvár and the national border at the south, can be considered to be partially regulated. As a result, the medium water regulation stabilized the main bed. However, both the increase in speed due to narrowing and the increase in fall due to shortening are associated with an increase in the sediment carrying capacity of the river, and thus a bed-deepening process has been started. In order to stop the water level lowering process, the regulatory structures have been built in the last 20 years with a lower level and a modified layout.

To the north of the water intake location of the NPP, just above the city of Paks, the Danube turns a large bend from the west to the south. As a result, the drift line swings towards the right bank, thus along and below the bank line that runs along the city, this concave bank is protected by stone cladding against lateral erosion. As part of the stabilization of the river's mid-waterbed, spurs were established on the convex shore every 600-750 meters between 1,530-1,533 rkm. The formation of reefs along the left bank is still ongoing, up to 1,525.5 rkm.

At 1,526 rkm, the drift line is moved close to the left bank. During the re-routing of the warm-water channel of the NPP, where the right bank is gradually widening, there is an approximately 2 km long reef island near the right bank. The tendency of reefing, which is unfavourable to navigation, was regulated several decades ago with spurs in such a way as to allow the continuous natural accretion of bays. At the same time, along with the right bank security, short spurs were built on the opposite side at Uszód every 400 m. They have also completely stabilized the left bank line.

The current flow of the Danube is primarily determined by the snow melting and rainfall in the Alps. Its floods are typically associated with early spring snow melting and early summer rainfall and glacier melting. In the sections of the NPP at 1,527 rkm, the water level change can be characterized by the measuring station in Paks (1,531.3 rkm), which has been in operation since 1 January 1868. The height of the ‘0’ point of the scale is 85.38 mBSI. The lowest water level (LWL) since the start of monitoring is -97 cm (84.41 mBSI, 26 October 2018). The highest ice-free water level (HWL) is +891 cm (94.29 mBSI) and was detected on 11 June 2013. The largest ice water level (HWL) was formed on 27 February 1876 with a water level of +1,006 cm.

(95.44 mBSl). The annual absolute change in water level depends mainly on the peak level of floods: Mostly 6-7 m, but in some years with extreme water flow close to 9 m.

The filling level in the NPP site is 97.00 mBSl. This is nearly 3.0 m higher than the prevailing flood level (94.05 mBSl) and about 1.4 m higher than the ice-free flood level with a return time of 10,000 years (with a calculated probability of occurrence of 0.01%) and higher than the 96.60 mBSl crown level of the Danube's left bank flood protection embankment in the power plant section. Taking all this into account, in terms of flood protection, the NPP site can be considered safe. Under current water downflow conditions, the occurrence of a resulting in a flooding of the NPP site can be ruled out.

The average depth of the Danube bed in the area of the NPP is 4 m below the low water level and 5-6 m along the drift line. The material of the bed is mainly gravelly sand and sandy gravel. Under the mouth of the warm-water channel, the increased water speed and turbulence resulted in a significant deepening of the bed. At the same time, the height of the right side reef (Uszód reef) increased, permanent vegetation settled on its surface, and the deposition of fine-grained overlay sediment over the gravel sand began. It can also be explained by the deepening of the small waterbed that a thin, long reef began to form along the left bank between 1,526.6-1,526.1 rkm)

2.1.8. Demographic characteristics

The presentation of demographic characteristics was primarily based on situational analysis, the aim of which was to review the current, partly recent demographic and population trends, and to a lesser extent complemented by long-term time-series assessments after 1990 based on the data of the Hungarian Central Statistical Office (HCSO). This includes the identification of changes in population size, the evaluation of the regional differences in the geographic distribution of the resident population, and the assessment of the demographic characteristics (e.g., composition) of the population, concerning the site and its 75 settlements in the 30 km zone involved in the assessment. Descriptive statistical analyses, mainly based on census databases, allow for settlements assessments, but are not suitable for presenting differences within the settlement. These results also provide the basis for pre-calculation of population change.

According to the 2022 census, the resident population of the site and its surrounding area (Paks region) was 203,961 (2.1% of the country's population). In the vast majority of the settlements involved in the assessment, a continuous population decline has been observed since 1990, in line with national trends. Over the 32-year period involved in the assessment, the population decreased by a total of 38,785 people (*Table 2.1.8-1.*). The rate of decline (16 percentage points) was nearly double the national decline that occurred between 1990 and 2022 (8 percentage point).

Table 2.1.8-1. Change of the resident population in Hungary and in the Paks region (1990-2022)

Area	Resident population [number of persons]				Change between 1990 and 2022 [number of persons]	Rate of change between 1990 and 2022 [%] (1990=100%)
	1990	2001	2011	2022		
Paks region	242,746	241,642	223,947	203,961	-38,785	-16.0
Hungary	10,374,823	10,200,298	9,985,722	9,610,403	-764,420	-7.0

Source: Hungarian Central Statistics Office (HCSO) census data

The distribution of some of the main demographic indicators in the Paks region highlights the territorial differences between settlements based on data from the 2022 census (*Table 2.1.8-2.*). There are typical differences between towns and villages, mainly according to the population size categories of settlements.

Table 2.1.8-2. Distribution of some demographic indicators in the settlements of the Paks region in 2022

Settlement	Resident population [number of persons]	Ageing index* [%]	Number of live births [number of persons]	Number of deaths [number of persons]	Number of in-migration [number of persons]	Number of out-migration [number of persons]
Foktő	1,409	145.7	9	31	75	105
Vajta	791	107.6	9	8	62	55
Sáregres	687	97.6	11	9	47	50
Miszla	255	229.2	3	7	16	23
Fajsz	1,532	170.1	17	20	97	100
Bogyiszló	1,982	139.0	20	40	106	103
Géderlak	864	158.2	9	18	61	78
Kistormás	272	117.4	4	5	30	27
Dusnok	2,671	149.3	15	36	110	122
Paks	**17,827**	**153.0**	**157**	**179**	**796**	**1,016**
Gerjen	1,151	138.2	9	19	52	50
Kalocsa	14,619	201.3	96	250	761	834
Bölcske	2,593	136.5	26	34	169	158
Varsád	337	151.2	1	4	23	19
Nagyszékely	380	105.1	2	5	20	28
Tengelic	2,013	176.9	17	30	160	164
Nagykarácsony	1,308	133.5	12	22	100	104
Drágszél	288	293.5	4	8	46	40
Dunapataj	3,017	199.0	15	49	235	208
Öregcsertő	708	193.0	2	14	66	50
Őcsény	2,213	140.8	14	35	189	158
Kiskőrös	13,320	166.1	92	228	586	552
Pálfa	1,435	156.1	12	26	117	69
Dunaszentgyörgy	2,434	117.6	27	30	151	154
Kölesd	1,322	109.1	16	21	72	109
Császártöltés	2,115	216.3	11	28	107	103
Tolnanémedi	922	168.1	7	15	57	69
Dunaszentbenedek	714	145.8	5	17	37	45
Bátya	1,825	176.1	16	39	135	120
Bikács	381	150.0	2	5	31	35
Györköny	985	134.4	12	12	76	58
Cece	2,529	105.7	30	35	163	133
Kajdacs	1,062	111.4	19	20	110	75
Harc	769	102.3	5	15	60	67
Dunatetétlen	510	160.6	4	5	31	23
Németkér	1,539	145.2	18	30	90	106
Szakadát	214	331.8	1	2	14	22
Felsőnána	570	88.2	4	12	26	43
Ordas	427	151.4	9	7	27	32
Uszód	846	168.0	4	15	86	92
Szedres	1,974	148.9	18	37	129	133
Nagydorog	2,462	117.9	22	34	152	130
Harta	3,368	208.5	28	48	155	179
Hajós	2,700	238.4	8	37	113	126
Fadd	4,012	123.5	35	61	279	260
Szakmár	1,082	179.3	7	25	97	94
Kecel	7,932	153.0	77	125	336	358

Settlement	Resident population [number of persons]	Ageing index* [%]	Number of live births [number of persons]	Number of deaths [number of persons]	Number of in-migration [number of persons]	Number of out-migration [number of persons]
Pusztahencse	917	95.5	10	14	60	84
Előszállás	2,419	125.5	22	36	185	156
Simontornya	3,581	185.1	29	66	225	216
Sárszentlőrinc	954	128.6	6	13	69	63
Dunaegyháza	1,458	122.7	12	25	160	124
Sükösd	3,340	176.6	17	77	200	194
Udvari	268	200.0	4	6	9	20
Zomba	1,849	181.4	13	22	91	115
Kéty	631	99.0	6	9	25	38
Akasztó	3,138	138.4	31	43	206	194
Szekszárd	30,057	212.6	215	484	1,826	2,073
Kalaznó	132	177.8	1	2	7	13
Fácánkert	664	95.2	5	6	76	55
Tolna	10,697	158.9	92	152	528	613
Alsószentiván	543	195.2	6	12	62	51
Sióagárd	1,183	154.3	4	19	95	78
Alap	1,856	116.3	23	44	124	92
Kisszékely	290	506.7	1	6	37	26
Homokmégy	1,191	197.9	11	18	104	90
Solt	5,990	160.6	59	93	340	348
Madocsa	1,746	119.3	18	24	74	95
Gyönk	1,648	329.9	9	82	167	98
Medina	688	112.0	4	13	63	42
Miske	1,609	121.3	19	25	151	179
Dunaföldvár	8,176	135.4	59	136	533	485
Nemesnádudvar	1,636	161.3	16	24	51	71
Újtelek	364	346.4	1	11	34	22
Daruszentmiklós	1,072	85.6	14	17	126	114

* A measure of population aging, which also projects future trends, shows the ratio of the elderly (aged 65 and over) to the population aged 14 and under

Source: HCSO census 2022

Based on the 2022 census, the geographical location of the population is characterized by an urban-rural divide. Szekszárd, Paks and Kalocsa are the most populous, but generally, cities account for the vast majority of the local resident population. The villages and large villages were primarily affected by the population decline observed in the region. There are settlements (e.g. Szakadát, Udvari, Kalaznó) where the population fell by nearly half between 1990 and 2022. By 2022, the population of cities fell to 75-90% of the 1990 figure. Settlements located in Tolna county experienced a more moderate population decline than the county average. In the settlements involved in the assessment within Fejér county, the decline was in line with the county average, while in the case of those located in Bács-Kiskun county, the decline was greater than the local average during this period.

In addition to population decline, changes in the age composition also resulted in significant demographic transition in the site and its surroundings compared to 1990. The proportion of younger age groups steadily decreased, while that of older age groups increased, at a greater rate than the national average. The proportion of people aged 0-19 within the total population decreased by nearly 10 percentage point by 2022 compared to 1990, while the proportion of those aged 60 and older increased by more than 10 percentage point. No decline in proportion was observed in the age group of 40-59 (*Table 2.1.8-3.*) As a result of changes in the age composition, the dependency ratio was 67.6% in the Paks region and 54.0% nationwide in 2022.

Table 2.1.8-3. Changes in the proportion of age groups within the resident population in the Paks region (%) between 1990 and 2022

Age group	1990	2001	Change between 1990 and 2001 (percentage points)	2011	Change between 2001 and 2011 (percentage points)	2022	Change between 2011 and 2022 (percentage points)	Change between 1990 and 2022 (percentage points)
aged 0-19	28.1	23.4	-4.7	19.4	-4.0	18.7	-0.7	-9.5
aged 20-39	28.0	27.2	-0.8	26.3	-0.9	22.3	-4.0	-5.6
aged 40-59	25.0	28.5	3.5	29.4	1.0	29.5	0.1	4.5
aged 60≤	18.9	20.9	2.0	24.9	4.0	29.5	4.6	10.6

In the gender distribution of the population, there is a surplus of men up to the age of 60, after which women become the majority. Based on the entire population involved in the assessment, there is an overall surplus of 6,033 women (2022).

In the past 30 years, the proportion of the elderly population has steadily increased in the site and its surroundings, which led to a rise in the aging index and also affected the territorial distribution of people over the age of 60. The average value of the indicator is 189.9% in the assessment area, which significantly exceeds the national average (141.5%) (2022). The proportion of the elderly population is particularly high in villages with small populations.

The population decline and the change in the age structure are caused by negative natural vital events trends. Natural population decline has been present in the demographic situation of the site and its surroundings since 1990, and its value has increased nearly sixfold since then. The live birth rate for the population living here was 8‰ (national average: 9.1‰), the death rate was 15.8‰ (national average: 14.1‰), the natural population decline was -7.7‰ (national average: -5.0‰), and the total fertility rate was 1.51 (national average: 1.52) in 2022. The number of births has been declining steadily since 1990, but the recent increase in the mortality rate is likely the result of the COVID-19 pandemic between 2020 and 2022.

The negative sum of natural increase was further exacerbated by net migration loss, and as a result, the actual growth rate – that is, the actual change in population, including the impact of migration – was also negative in the site and its surroundings after 1990. While between 1990 and 2001, 22 out of the 75 settlements involved in the assessment experienced actual increase – that is, its population increased – between 2011 and 2022, there was only 4 such settlement (Fácánkert, Györköny, Dunaegyháza, Harta). In absolute terms, the largest actual population decline – more than 1,000 people – affected settlements with larger populations (Szekszárd, Kalocsa, Paks and Solt) in the recent years.

Regarding other demographic characteristics, based on data from the 2022 census, it can be observed that in the site and its surroundings, the number of families, married couples, and households has decreased since 2001, while the number of single-person households has increased; however, these trends are consistent with national trends. It is positive that the number of employed persons per 100 households has increased slightly, but this is primarily due to Paks and Szekszárd. There has been a steady improvement in educational attainment in Paks and its surroundings, particularly since 2001. The proportion of people with low educational attainment decreased significantly, the proportion of those with secondary education – primarily high school diplomas – has increased, and the proportion of those with higher education has doubled over the past 20 years, accounting for 14.6% of the educational attainment of the population over the age of 7 (2022).

Overall, the population change in the site and its surroundings is determined by population decline, age structure changes and the decline in the share of the working-age population, the acceleration of ageing and, in most cases, negative migratory factors (out-migration). These demographic factors and processes have an impact on future population developments. During the period between 2026 and 2030s, the number of people temporarily living in Paks and its

surroundings may increase during the construction of the Paks II NPP. However, this change is expected to adjust back in line with the trends described above after commissioning the new units.

2.2. Description of the planned activity

The operation of Paks NPP during the SSLE period is planned with the power plant technology, production capacity and material use characteristics currently in use, with a further use of existing electricity production equipment and infrastructure. However, as a result of the technical analyses and feasibility studies related to the preparation of the SSLE, the MVM Paksi Atomerőmű Zrt. planned some technical and technological modifications and several technological reconstructions, the environmental impacts relating to the implementation of which and the operation of the modified systems had to be analysed and evaluated in this assessment. The main task of the modifications belonging to this scope relating to the environmental impact is the construction of the peak cooling system ensuring compliance with the temperature limit for the Danube – even in the time of joint operation with the Paks II NPP – as well as the construction of the related warm-water channel section. The planned technical modifications are described in detail in *Chapter 2.2.2.*

The main technological equipment and their tasks set out in Annex 1 to existing environmental license ref. No. 391-18/2017 of the Paks NPP, which are relevant for the environmental license, do not fundamentally change due to the SSLE, but their operating period is extended. The technical conditions for the continued operation of existing equipment are created by the maintenance and reconstruction activities described in *Chapter 2.2.3*.

2.2.1. General description of electricity production facilities, technology and operational processes

2.2.1.1. The Paks NPP's technology, main technical characteristics

There are four reactors type VVER-440/213 in the Paks NPP. The name VVER derives from the abbreviation "water-water energy reactor" and the number "440" indicates that the original nominal electrical power of the NPP unit was 440 MW. The total electrical power of the power plant was thus 1,760 MW. During the period since the first unit was commissioned, the electrical performance of the units 1-4 increased to 470 MW per unit as a first step due to the modernization activities carried out in the power plant, and then to 508.6; 506.0; 506.0; 506.0 MW per unit respectively as a result of the implementation of a further power increase, thus increasing the total nominal electrical power of the facility to 2026.6 MW.

The reactors are power plant systems with light water-cooling, and saturated steam cycle using a thermal reactor with light-water moderator to slow down fast neutrons to maintain a chain reaction necessary for energy production. Each unit has a two-circuit design. Accordingly, they consist of a radioactive primary circle and a not radioactive secondary circle. Basic technical parameters of reactors are summarized in *Table 2.2.1.1-1.* The schematic diagram of the main equipment of the NPP and the theoretical operation of the power plant cycle process can be seen in *Figure 2.2.1.1-1.*

Table 2.2.1.1-1. The main technical parameters of the reactors of the Paks NPP

Reactor type	Pressurized water reactor type VVER-440/213
Thermal power of the reactor	1,485 MW
Number of loops per reactor in the primary circuit	6
Total volume of the primary circuit	237 m^3
Primary circuit pressure	123 bar
Coolant temperature	299.5 °C
Number of turbines per unit, per reactor	2

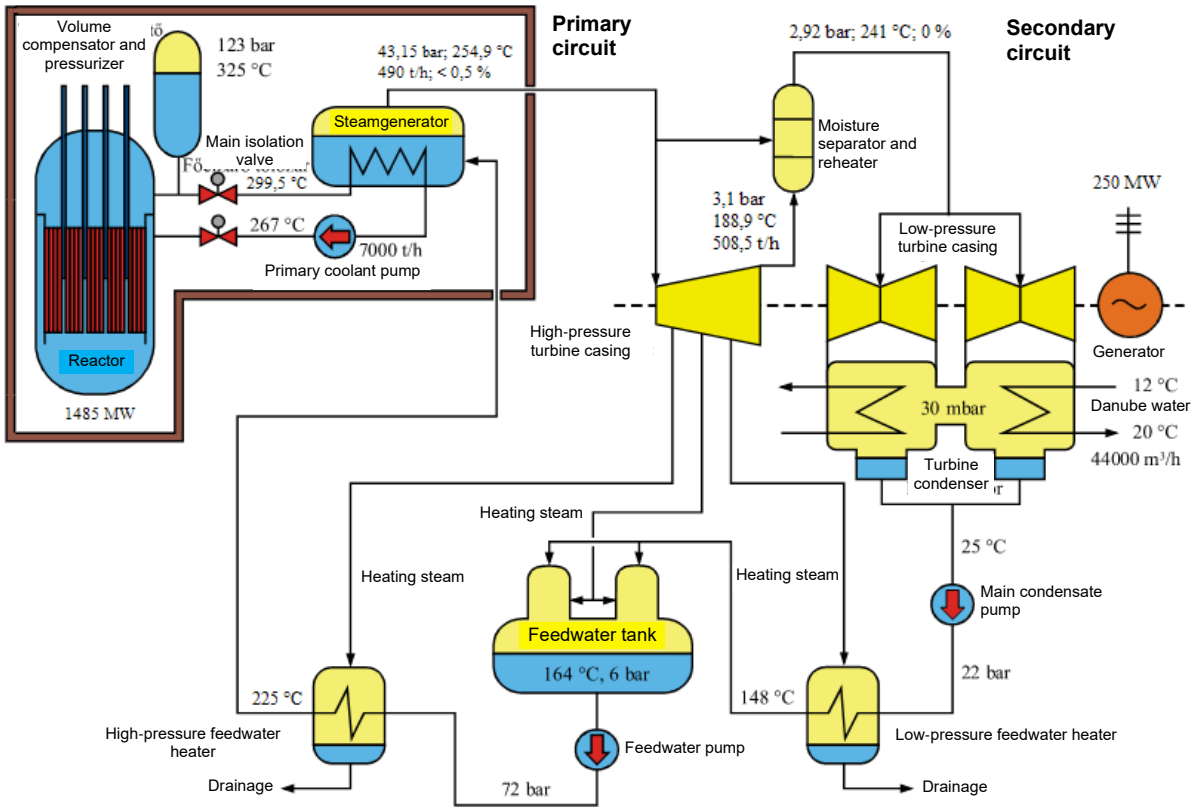


Figure 2.2.1.1-1. Schematic diagram of the main equipment involved in energy production

The energy generated by the fission of ^{235}U isotopes in the uranium dioxide fuel of fuel assemblies located in the core of the reactor by thermal neutrons is absorbed by the primary coolant (water at a pressure of 123 bar and a temperature of 267°C). The water of the primary circuit is under high pressure (123 bars); therefore, the water would not boil even at high operating temperatures. Water heated to 299.5 °C is fed into the steam generator, which transfers its heat to the water of the secondary circuit in its small diameter pipes. The pressure of the water in the secondary cooling circuit is much lower (43.15 bar) than that of the primary circuit, so the heated water in the steam generator boils. From here (after moisture separation), the steam is transferred to the high-pressure, then to the low-pressure turbine, the saturated steam operates the turbines. The generators powered by the turbines produce electricity. The steam escaping from the turbine is liquefied in the condenser, from where it is returned to the steam generator after preheating. The water of the primary and secondary circuit does not mix with each other, the radioactive materials that get into the coolant remain in the primary circle, do not get into the turbine or condenser. The secondary circuit steam phase coolant cools down by converting the heat into mechanical energy, and the remaining heat is released by heating the condensers on the river side, which is cooled with the Danube's water. Heated cooling water is returned to the Danube.

The most important technological equipment for the primary and secondary circuits are the followings:

- Primary circuit:
  - reactor vessel and upper unit,
  - reactor coolant line and main gate valve,
  - reactor coolant pump,
  - steam generator,
  - pressurizer and steam relief system.
- Secondary circuit:
  - saturated steam turbine,
  - generator,
  - condenser,

- low pressure pump,
- low pressure pre-heaters,
- Deaerator reduction valve,
- high pressure pre-heater,
- main feedwater pumps,
- moisture separator and reheater.

The NPP operates as a basic power plant with a relatively even load. The electricity produced is connected to the national grid at a voltage level of 400 and 120 kV respectively. The electrical feed-in system is designed in such a way that the operation of the vital security equipment of the units is ensured even in the event of disconnection from the national grid.

Design and equipment of the primary circuit

The primary circuit consists of a vessel-type reactor, 6 parallel connected loops and a pressurizer and steam relief system connected to one of the loops. Each loop is equipped with a reactor coolant pump, a steam generator and two main gate valves, as well as a stainless-steel pipeline with a diameter of 500 mm connecting the equipment. The reactor consists of the following structural elements:

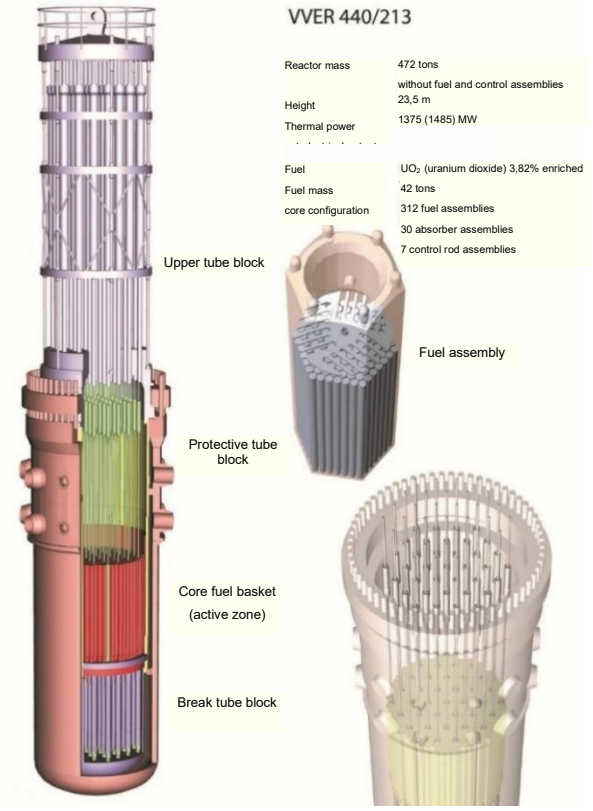


Figure 2.2.1.1-2. The reactor pressure vessel

- Reactor pressure vessel: Its task is the safe production and transfer of thermal energy generated by a controlled, self-sustaining nuclear chain reaction in the active zone to the primary circuit. In order to fulfil this function, the vessel must, on the one hand, ensure the location of the structure elements necessary for the thermal-producing process, their proper fastening and biological protection, and, on the other hand, it must also be possible to provide the maintenance conditions necessary for the fuel to be changed on a cycle-by-cycle basis. The reactor pressure vessel is a vertical cylindrical vessel with an elliptical top and bottom (*Figure 2.2.1.1-2.*). The vessel is made of high-strength alloy carbon steel, the inner surface of which, as well as the surface of the main joint, is coated with corrosion-resistant stainless steel (cladding) to reduce corrosion.
- Equipment within reactor pressure vessel: Equipment inside the reactor pressure vessel (shaft, shaft bottom, removable cask, protective tube unit and intermediate bar) is used to fix the active zone in the reactor pressure vessel and control the flow of the coolant within the reactor.
- Active zone: The active zone is the part of the reactor where large amounts of thermal energy are released by the controlled chain reaction. Active zone total
  It consists of 349 hexagonal block-shaped fuel assembly, of which 312 fixed position fuel assembly and 37 movable control and safety (SZBV) rods. The equivalent diameter of the zone is 2.66 m, its height is 2.5 m. The fuel assemblies are fixed at the bottom by the cask bottom, and at the top by the plate of the protective tube unit, ensuring their vibration-free grip.
  The VVER-440 type power plants use low-enriched ceramic uranium dioxide fuel. The fuel assemblies are units of NPPs' nuclear fuel, the basic task of which is the production of

thermal energy through the decomposition of fissile material. The building currently has a 15-month operating cycle, fuel assemblies spend several cycles in the reactor.

- Upper unit with drives of the control and safety system (SZBV): Its task is to seal the reactor vessel from above, and on it are located the drives of the reactor control and safety system, the measuring cables and connectors of the measuring system inside the vessel, the outlet and sealing of the measuring cables, as well as the protective pipes. The upper unit prevents the reactor shaft from moving upwards. The main elements of the upper unit: top head, SZBV drive casings, collectors and pipelines for the SZBV drives' cooling circuits, venting collector and its pipes, traversers, metal structures of the thermal insulation unit of the top head.
- Sealing elements of reactor main joint: The function of the sealing elements of the reactor main joint is to ensure the sealing between the reactor pressure vessel and the upper unit.

The primary circuit also includes the following equipment:

- Reactor coolant line and main gate valve: The function of the reactor coolant line is to lead the primary circuit coolant, heated by the thermal energy generated in the active zone of the reactor, from the outlet nozzle of the reactor to the steam generator, from there to the cooled medium to the reactor coolant pump, and then to the inlet nozzle of the reactor. The main gate valves located in the hot and cold branches of the loops are designed to separate the part of the loop containing the steam generator and the reactor coolant pump from the reactor if necessary.
- Reactor coolant pump: Its task is to circulate the primary circuit coolant through the reactor, the primary circuit loops and the steam generators, thus ensuring the transfer of the thermal energy generated in the reactor to the steam generator and the cooling of the fuel assemblies. Circulation of the primary circuit water is carried out by one pump per loop, which is located in the cold branch of the loop.
- Steam generator: Its task is to transfer the thermal energy produced in the reactor to the secondary circuit coolant, thus producing the dry saturated steam needed to drive the turbines. The steam generator is a horizontally arranged cylindrical heat exchanger with suspended heat transfer tube bundles and an elliptical lid at both ends. The primary circuit coolant flows within the tube bundles, which, by transferring heat from the primary circuit coolant to the secondary circuit coolant, ensure the production of dry saturated steam on the secondary side and hermetically separate the radioactive primary circuit from the secondary circuit.
- Pressurizer and steam relief system: The function of the pressurizer and steam relief system is to create pressure when starting the unit and to maintain the circle at constant pressure in stationary operation mode and to limit pressure fluctuations in transition operation modes. In addition to maintaining pressure, an important function of the pressurizer and steam relief system is to regulate the volume of primary circuit water. The pressurizer and steam relief system is a vertically arranged, insulated carbon steel tank with an austenitic cladding on the inner wall.

The auxiliary systems connected to the primary circuit are as follows:

- Make-up water and boron control system: The task of the system is to replace controlled and uncontrolled leakages in the primary circuit, to ensure the balance of the primary circuit water plant, and to compensate for slow changes in reactivity by changing the concentration of boric acid solution. In case of failure incidents, boric acid is introduced into the primary circuit as part of the reactor protection operation, ensuring proper subcriticality.
- Primary circuit water purification systems: An important factor in the safe and proper operation of the primary circuit technology equipment is the cleanliness of the primary circuit coolant, which is achieved by continuous water purification. The water purification tasks related to the primary circuit are provided by six independent systems. Water purification systems shall perform the following tasks:
  - purification of the primary circuit coolant in a partial flow,

  - purification of primary circuit-controlled leakages and drainage waters, provision of purified and sufficiently concentrated boric acid solution for other primary circuit technological systems,
  - purification of primary circuit floor water,
  - purification of the boron solution of the spent fuel pool and refuelling pool, the emergency boric acid tanks and other bubbler condensers,
  - purification of the blowdown of steam generators on secondary side,
  - recovery of concentrated boron solution from the coolant released during start-up and boron control.
- Controlled leakage system, leakage control systems: Its task is to preserve the quantity of the primary circuit coolant medium by collecting and returning to the main coolant system the primary circuit water that was leaked from the main coolant system's equipment in a controlled way and the primary circuit water that was leaked in other controlled ways. The leakage control system makes it possible to monitor the tightness of the flanged connections of the main coolant system's equipment and provides the operator with continuous information on the condition of the flanged connections of the main coolant system's equipment.
- Intermediate cooling circuits: Elements of the main equipment of the primary circuit require continuous cooling. Since this equipment is in direct contact with the primary circuit water, a closed-circuit intermediate cooling circuit has been inserted between the ambient water providing cooling and the equipment to be cooled. The radioactivity of the closed-circuit demineralized water is continuously monitored. Intermediate cooling circuits are provided by the drives of the control and safety rods, the reactor coolant pump, the pumps of the zone emergency cooling system.
- Special sewer and floor water system: Its purpose is to collect and pre-purify the floor water of the main and auxiliary buildings from mechanical contaminants by sedimentation and filtration. All rooms of the reactor building have a special drain for the reception of liquid on the floor. Water from the drains in the pipelines gravitationally flows into the sump tanks, from where it is transferred to the water purifier.

The secondary circuit

The task of the secondary circuit is to provide heat removal from the primary circuit through the steam generators, which deliver 46 bar dry saturated steam produced in the steam generators to the two turbine generators and return the resulting condensate to the steam generators. In the case of cooling and failure, it ensures heat removal from the primary circuit through the steam generators. The systems performing the heat removal function on the secondary side are as follows:

- Main steam supply system: On the one hand, its task is to supply the fresh steam produced in the steam generators to the turbines in order to satisfy the demand of the turbines for working steam, thereby transferring the heat generated in the primary circuit to the secondary circuit. On the other hand, it ensures the supply of auxiliary steam systems and also participates in the cooling and heating of the unit. The steam generated in 6 steam generators is transported to the main steam header via a separate steam line for each steam generator. Safety valves, quick-acting pneumatic disconnecting valve and main steam valves have been installed on each main steam line.
- Turbine and generator: The thermal and kinetic energy of the steam generators must be converted into a mechanical rotating motion in order to turn the generator into a rotation and thereby generate electricity. In this energy conversion process, the steam turbine's task is to convert the thermal energy of the saturated steam produced in the steam generators into mechanical energy (rotating motion), thus contributing to the process of heat removal on the secondary circuit. One unit has two turbines, the turbine consists of a three-cylinder design, a high-pressure cylinder and two low-pressure cylinders. The generators are two-pole, three-phase synchronous machines, the rotor is directly hydrogen-cooled and the

stator winding is directly water-cooled, the heat dissipation of other active parts (sheet body) is done by surface (indirect) hydrogen cooling.

- Moisture separator and reheater: The steam turbines of the NPP run on dry saturated steam. The initial moisture content of the steam entering the high-pressure cylinder is approximately zero, which increases continuously in the turbine as a result of a series of expansions. The moisture content of the steam leaving the high-pressure cylinder is so high (about 12%) that it is no longer suitable for further work. Therefore, a moisture separator reheater equipment was installed in front of the low-pressure cylinders. In the moisture separator, the water droplets are mechanically separated first, then by reheating the steam in the two reheating stages, the residual moisture content is removed.
- Main condensate system: The water generated by the condensation of steam is transferred from the condenser into the feedwater tank, then the feed water system supplies the steam generators from the feedwater tank. The two turbines belonging to the same unit have one main condensate system with the same structure.
- Feed water system: Its task is to supply the feedwater stored in the feedwater tanks to steam generators, to preheat the feedwater on the high-pressure preheaters and to participate in the cooling and heating of the primary circuit. The operational feedwater system consists of 2 deaerator feedwater tanks, 5 main feedwater pumps, 6 high-pressure preheaters and 6 steam generator levelling valve units, as well as connecting lines and armatures.
- Demineralized water system: The function of the demineralized water system is to ensure the feedwater reserve of the units, to compensate for the coolant medium losses of the secondary circuit by feeding it into the condensers or feedwater tanks, and to supply gland closing and cooling water to the water cooling pumps, as well as the 46-bar main feedwater pump, in case of failure of the main condensate system. A demineralized water system is a common system by construction (a separate system to units 1-2, and units 3-4). The production of demineralized water is carried out by the make-up water preparation plant from Danube water. The demineralized water stock is stored in 3 tanks of 1,000 m^3 each. The tanks are standing, cylindrical, located next to the unit 1 and unit 3 in the courtyard.
- Cooling system: Through the secondary circuit, it is used to cool the primary circuit and dissipate the remanent heat. The system's task is to cool down the primary circuit at the appropriate speed through the secondary circuit when the unit is planned to shut down or in case of failure, to drain the so-called remanensh (residual heat) produced in the out-of-service reactor, and to help heat up the primary circuit when the unit is started. The cooling system is only put into operation in case of failure or normal cooling.

Cooling-water systems

The operation of many systems and equipment in the NPP requires adequate cooling water supply. The cooling-water system of the power plant consists of the following sub-systems: essential service water system, auxiliary circulating water system, main circulating water system. The cooling-water requirements of all three sub-systems are supplied according to different technological requirements, but ultimately from the Danube. Water intake structures belonging to the units 1-2 and units 3-4 ensure the intake of the required quantities of water through the cold-water channel of the NPP.

The task of the essential service water system is to supply equipment that requires safe, constant cooling in the normal operation of the unit with cooling water, and to cool the unit in normal and emergency conditions. Considering that the emergency core cooling system according to the safety philosophy of the power plant, it consists of three independent systems; in order to preserve the principle of independence, the cold-water essential service water system is also composed of three independent branches. The essential service water system is supplied with water by water pumps installed in the water intake structure.

The auxiliary circulating water system serves the cooling and other water needs of normal operational consumers participating in the energy production process and technology of the power plant. Consumers are not essentially (i.e. important for the nuclear safety of normal

operational consumers) equipment. The system, which is branched out of the main circulating water system, is powered by booster pumps and filtering equipment.

The main circulating water system provides the cooling water necessary for the conversion (condensation) of vapour from the turbines to precipitation and for the operation of certain auxiliary systems of the turbine and generator. The source of water is raw Danube-water, which passes through the cold-water channel to the water intake structure. The main circulating water system receives water from the main line of the water intake structure through four disconnections.

The water transported by the main circulating water pumps enters the raw water pool and flows gravitationally through the rest of the section. From the raw water pool, the water passes through four drum filters. The filtered water is transferred from the drum filters to the filtered water pool and from there (one per unit) to the main pipe. The main pipes have four connections to the condensers of the turbines. Water is transported from the two main pipes through a branch to the auxiliary pump room. The warmed cooling water is transferred from the condenser to the closed-section reinforced concrete channels, then through the weir with level-control function, the warm-water channel and the energy-breaking structure to the Danube.

Ventilation and air conditioning systems

Ventilation and air conditioning systems are responsible for ensuring that the air in potentially contaminated areas is properly extracted and managed, as well as the operating conditions necessary for the operation of the equipment and the presence of personnel.

Ventilation systems serve the operating rooms of the controlled zone of the NPP, and the premises of electrical and control safety systems located outside the controlled zone. The ventilation systems in the controlled zone and the ventilation systems outside the controlled zone are physically separated from each other. In exhaust systems where the exhaust air is expected to be contaminated with radioactive aerosols, the exhaust air passes through a filter. The air from the controlled zone shall be released into the environment only through the controlled release points, the ventilation chimney.

Emergency systems

The emergency systems of the NPP are designed to meet the safety requirements, i.e. they must ensure the safe operation of the active zone in the event of any failure of the normal operating equipment and must be able to prevent the release of radioactive materials into the environment to a greater extent than permitted. In order to meet this requirement, safety-relevant protection systems are designed to be redundant (multiple) or divergent (different) in order to eliminate failure of same origin. Emergency systems are as follows:

- Emergency core cooling systems: the basic safety equipment of the unit, the common purpose of which is to prevent damage to the active zone by the introduction of boron cooling water in the event of loss of coolant accidents, which could lead to unauthorized radioactive release.
- Steam generator emergency systems: Emergency and auxiliary emergency feedwater pump systems are available for reliable water supply to steam generators. The function of the emergency feedwater system is to ensure the water supply of steam generators from the deaerator feedwater tank in the event of failure of the feedwater pumps. The auxiliary emergency feedwater system provides steam generators with water supply from demineralized water tanks in the event of a large-scale failure in the feedwater supply, during which steam generators are at risk of drying out. There are two auxiliary emergency feedwater pumps for one unit. The pumps and other auxiliary emergency feedwater pumps of the other unit with the same construction are connected to the three 1,000 m^3 demineralized water tank with a common suction branch.

  In order to reduce the consequences of heat transfer pipe and collector breaks failures of steam generators, a blowdown system has been developed on the secondary side. The system of 5 valves placed under each steam generator is capable of venting a quantity of medium towards a hermetic space that guarantees that the pressure does not rise to the opening value of the steam generator safety valves even in the event of a break of pipe of

the largest cross section. The design of the system effectively reduces activity avoidance to zero in the event of such a failure.

Localization systems

The power plant's room system designed for overpressure, i.e. hermetic space, the building structure comprising the primary circuit. Its task is to prevent the release of radioactive media into the environment in the event of a loss of coolant accident. The building structure has been dimensioned according to the pressure in the event of a design failure. The localization system shall comprise:

- Passive pressure reduction system (localization tower): Its task is to reduce the steam pressure generated by the expansion of the overheated coolant in the emergency damaged state of the primary circuit by condensation. The localization tower consists of two main parts, the bubbler condenser and hoods. In the event of a pipe break failure, the stream condenses through the water layers of the bubbler condenser plates, and the air is transferred to the hoods due to pressure difference.
- Sprinkler system: It is an active element of the pressure reduction system of the containment, its task is to reduce the pressure in the hermetic space during the failure, to absorb iodine in the atmosphere of the hermetic rooms and to cool the atmosphere.
- Isolation system of hermetic space: Its task is to isolate the hermetic rooms and their technological system from the environment during the failure in the hermetic space resulting in the release of radioactive materials.
- Hydrogen management system: Its task is to remove hydrogen entering the hermetic space in case of failure.

Electrical equipment, safety diesel generators

The four units of the power plant, as a basic power plant, produce electricity for the National Electricity System. Accordingly, the first part of the power plant’s electrical systems consists of equipment producing electricity and delivering it to the national grid. The electricity generated by the power plant's steam turbine generator units is transported to the generator through an isolated phase busbar, with generator terminal voltage circuit breaker transformers, which transforms it to a voltage level of 400 kV. The two generators belonging to one unit are connected to the 400 kV substation, which is part of the national basic network, through a unit line. Another significant part of the power plant's electrical equipment consists of auxiliary electrical equipment, which supply the technological systems with the auxiliary energy necessary for their operation.

Some of the power plant's technology is used to maintain nuclear safety. They require a so-called safety electricity supply to perform their safety function. The electricity outage time for some technologies should not exceed a fraction of a second. Uninterruptible electricity supply systems are used to feed such equipment.

In the event of an unexpected failure, power failure, or frequency breakdown on the auxiliary network, the diesel generator units belonging to the given unit start automatically and provide electricity supply to the technological systems concerned as a stand-alone energy source connected to the emergency power supply system. Due to the triple redundancy of the safety systems, three independent diesel generators are installed per unit, which are stationary air pollution point sources.

The units 1-2 are equipped with 3-3 (two-stroke) diesel generators type 15D100 with a rated thermal input of 4,502 kW/pcs (electrical power 1.6 MW), the units 3-4 are equipped with 3-3 (four-stroke) diesel generator type 18PA4 V 185 VG GANZ-SEMT PIELSTIK with a rated thermal input of 6,285 kW/pcs. Diesel generators are in standby mode in addition to the normal operation of the unit, they are only started in operating conditions other than normal operation and during periodic, operational tests.

Instrumentation and control

An extensive control technology system is used to control the NPP's technology, nuclear and mechanical processes and equipment and to ensure its safe and economical operation. In all

operational states of the unit, the control technology system is responsible for providing the necessary protection and automatic operation, operator intervention possibilities and information specific to the given operational state, and for verifying the fulfilment of the given safety functions, as well as for implementing the prohibition of unauthorized interventions.

Radioactive waste management

On the Paks NPP site, radioactive waste generated under operation is temporarily stored, which may be solid or liquid. Radioactive wastes are classified into very low activity, low and intermediate activity and high activity categories according to activity concentration and dose rate. The main sources of solid radioactive waste generated during the operation of the NPP:

- worn-out and activated or surface-contaminated equipment, fittings, thermal insulation, etc.,
- construction materials from modifications (concrete debris, wooden material, etc.),
- scrap metals, chips/shavings and worn-out tools from maintenance workrooms,
- soft waste generated during maintenance and operation (clothing, personal protective equipment, wipers, foils etc.),
- components taken from reactor (absorbents for control assemblies, intermediate rods, thermocouples, etc.).

The interim storage of low- and intermediate-level waste is ensured at the NPP site by reducing the volume and preparing waste packages suitable for disposal. After the interim storage, these radioactive wastes are deposited in the National Radioactive Waste Repository (NRWR) operated by PURAM, located in Bátaapáti. The compilation of waste packages that can be taken over for final disposal PURAM is ensured in the NPP by appropriate waste treatment and conditioning technologies.

The collection and treatment technologies of low- and medium-level solid radioactive waste are designed in such a way that the waste reception requirements can be met. They are stored in the main and auxiliary buildings of the power plant until they are handed over to PURAM. The following specific types of waste can be distinguished:

- Waste that can be placed in 200 litres drums.
- Large waste not to be placed in 200 litres drums:
  - after cutting, they can be placed in larger containers and handed over for final disposal filled with cement paste.
- Borax from Liquid Wastewater Processing (FHF) technology:
  - the FHF technology can produce a releasable quality metaborate, the reclaimed borax is disposed of as hazardous waste after releasing.
- Various filter cartridges:
  - cesium-loaded filters generated by the FHF technology are packaged in containers without treatment after radiation dosimetry.

When scheduling the delivery of waste packages, it is taken into account that there should always be at least one year of spare capacity at the power plant site for any recovered radioactive waste packages, or waste generated in the event of unexpected events.

With the cooperation of the MVM Paksi Atomerőmű Zrt. and PURAM, a waste package construction has been developed, with which the storage spaces to be constructed in Bátaapáti NRWR can be used cost-effectively at the same level of safety. For the disposal of low- and intermediate-level solid waste, braced metal containers are used, in which 4 pcs of 200 l drums are placed. The free cavities of the waste packages are filled with cement paste made from liquid radioactive waste (this process allows the deposit of additional radioactive waste). The production of compact waste packages takes place on the NPP site, the delivery to NRWR takes place by road, using a truck designed for this purpose and licensed by the authorities. Operationally production of new waste packages is expected to start in 2029.

Liquid radioactive waste (evaporation residue, evaporator acidification solutions, used primary circuit ion exchange resins) are collected in interim liquid radioactive waste storage tanks in the auxiliary building. Liquid radioactive waste that cannot be treated by the FHF technology is

solidified in the NPP before being transported to the final storage facility, because only solid waste can be deposited in the final storage facility.

The operational use of the liquid waste processing FHF technology started in 2010, the operation of the technology frees up storage capacity, thus the interim storage of liquid radioactive waste is ensured in the long term, also taking into account the commissioning of the cementing technology, which will be used for the solidification of liquid waste. The solidification of liquid fast waste is carried out per storage tank, the cementation recipe corresponding to the chemical composition of the waste in the tanks can be applied after individual official licensing. When scheduling the processing and conditioning of liquid radioactive waste, it is taken into account that there should always be at least two years of spare capacity for waste generated in the event of unexpected events.

High-level solid radioactive waste is temporarily stored in dedicated pipe wells on the NPP area. Large-scale waste that cannot be placed in storage wells, they can be collected in lead containers. According to the high-level waste management concept, until the decommissioning of the NPP, the waste is temporarily stored on the site, and during decommissioning, the PURAM treats it together with the other high-level waste and places it in the final storage facility for the disposal of high-level waste already in operation at that time.

Part of the gaseous radioactive waste generated during the operation of the NPP is cleaned by the filtration equipment of the ventilation systems. The hydrogen combustion system dilutes and incinerates the dissolved gases (hydrogen, noble gases, oxygen, etc.) in the primary circuit coolant and in the medium added as make-up water, a controlled way. The special gas cleaning systems continuously receive and clean the gas mixtures generated at the units, which, after cleaning, enter the ventilation chimney.

Handling and storage of fuel assemblies

The handling and storage of the fuel assemblies used as fuel for the NPP can be divided into two parts. The first one is handling and storage of fresh fuel arriving in the power plant. Before their use in the reactors (radiation), radiological protection shielding or cooling is not necessary. Storage of fresh fuel, in the amount of stocks required for the economical operation of the power plant, per twin gate is provided in the dedicated room in the reactor hall.

In the case of radiated, or spent, i.e. in the reactor no longer used fuel assemblies, in addition to maintaining the subcritical state, radiation protection shielding and the drainage of residual heat generated in the elements must also be ensured during both treatment and storage.

The storage of radiated fuel in the power plant is provided by a so-called spent fuel pool in the immediate surrounding of each of the four reactor facilities. The function of the spent fuel pool is to store the spent fuel assemblies after they have been unloaded from the reactor until the specific activity and heat development of the fuel is reduced to a value that already allows the delivery of the spent fuel from the power plant using the available transport technology. The spent fuel pool is connected by a refuelling channel to the upper part of the reactor shaft, the refuelling pool. The spent fuel pool has a self-contained cooling circuit, which provides drainage of the residual heat of the fuel assemblies.

After 3-5 years of storage in the spent fuel pool, the spent fuel assemblies are currently transported to SFISF with a dedicated C30 transport system, a special transport container filled with water and railway equipment, thus ensuring the free spent fuel pool storage capacity necessary for the continuous operation of the reactors. The system consists of a special TW-C30 container transport wagon and a transport container with a storage capacity of 30 spent fuel assemblies. The spent fuel assemblies to be transported out of the spent fuel pool are placed in the C30 transport container in the shaft belonging to the reactor, and the fuel assemblies are dried in the SFISF after being removed from the transport container.

Communication and communication systems

The NPP has all the wired and wireless communication devices that ensure the operational communication of the power plant, the conduction of telephone traffic, the implementation of metering and signalling data transmission, speech and data connection with the electrical

industrial telephone system, the information and alerting of the employees, the authorities and the general public.

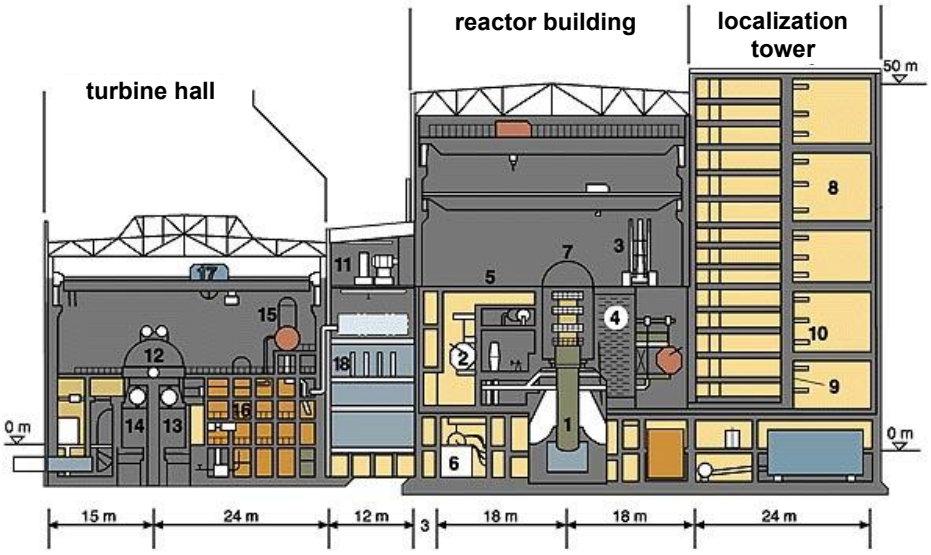
2.2.1.2. Energy production facilities

Each reactor is located in twin unit buildings (build-out I.: units 1-2., build-out II.: units 3-4.), the twin unit with two reactors is shown in *Figure 2.2.1.2-1.* The upper part of the reactor buildings is a standard industrial building with general mechanical equipment. In the lower part of the building there is a reactor room with the primary circuit and steam generators. The reactor is surrounded by radiation shielding. The lower part of the reactor building forms a separate, enclosed space per reactor. The separated parts of the building (so-called hermetic spaces) are connected to the reactors' own emergency and localization systems. Hermetic space means a pressure-resistant space that withstands the heat and pressure loads of a failure and ensures the retention of radioactive materials even in emergency situations.



Figure 2.2.1.2-1. View of the twin units of the Paks NPP

The security systems of the Paks NPP follow the principle of so-called in-depth protection, as part of which there are several systems between the environment and the nuclear fuel assemblies that prevent radioactive release (protection barriers). In addition to these passive barriers, there are also active protection systems. During and after failures, properly sized systems serve to cool the reactor. In the event of a power failure, auxiliary diesel generators are activated. *Figure 2.2.1.2-2.* shows the principal operational building and the cross section of the building complex containing the main power plant equipment.



1. Reactor
2. Steam generator
3. Refuelling machine
4. Spent fuel pool
5. Radiation shielding
6. Auxiliary feedwater system
7. Reactor hall
8. Localizing tower
9. Bubbler plates
10. Hood
11. Aerator
12. Turbine
13. Condenser
14. Turbine hall
15. Feedwater tank
16. Pre-heater
17. Turbine hall crane
18. Instrument rooms

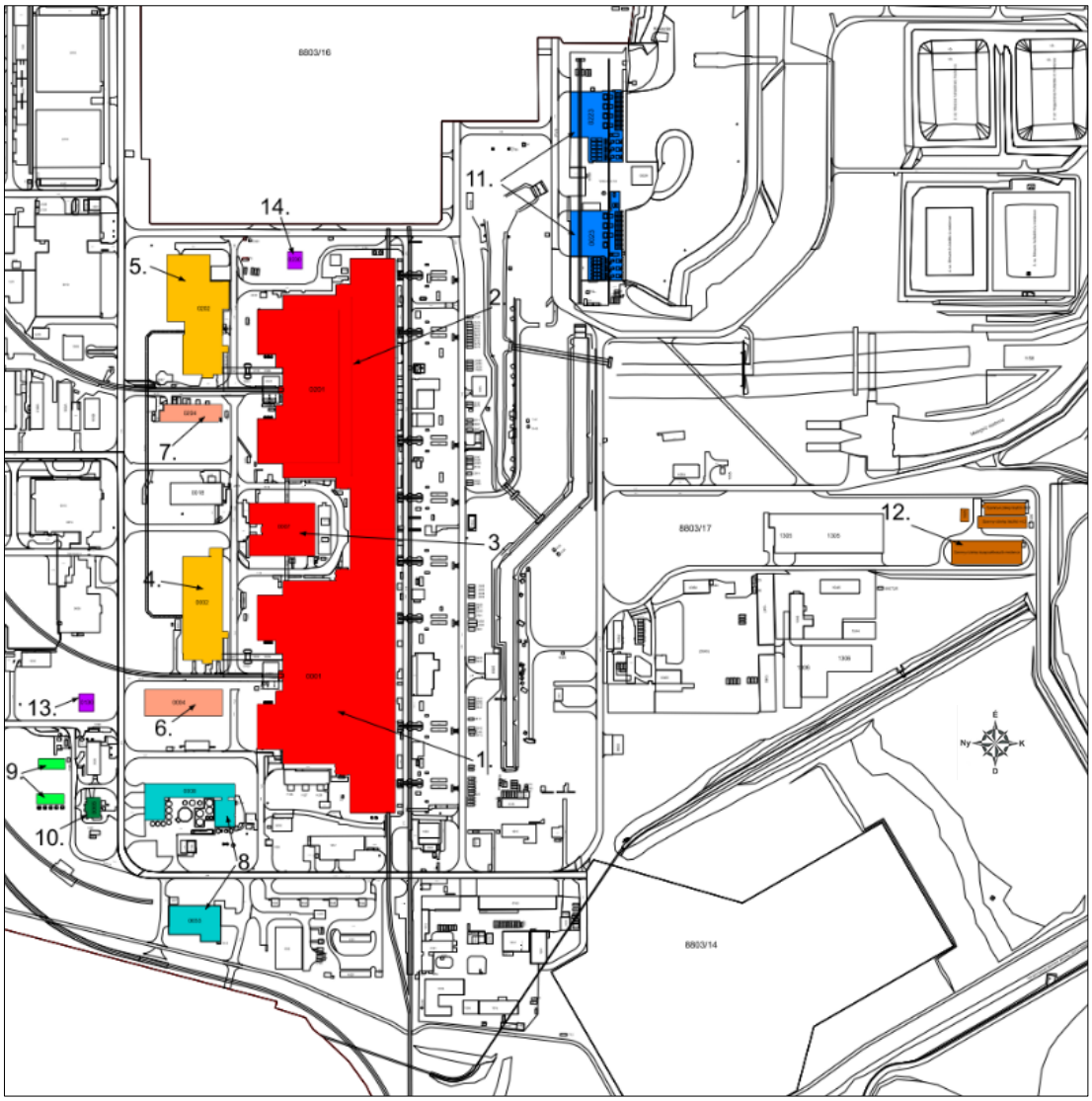
Figure 2.2.1.2-2. The cross-section of the building complex containing the main power plant equipment

Each of the four reactors has a common pressure cylinder located in the immediate surroundings of the reactor buildings. Each reactor has 2 turbines; the power plant has a total of 8 turbines. The generators are located directly next to the turbine building, but the switch area is located at a safe distance from the turbine building. Thus, for example, in the event of a fire, the switch area and the pressure cylinder do not endanger each other.

Regarding the design and layout of the power plant, the following main buildings, structures, architectural structures should be distinguished (*Figure 2.2.1.2-3.*) (offices, storage and other buildings on the site are not listed):

- Principal operational buildings: The centres of energy production, the buildings, are divided, from a design point of view, a combination of two units, which are essentially identical. According to the technology, the principal operational buildings are divided into parts containing the primary and the secondary circuit, as well as electrical switch rooms.
- Auxiliary buildings: One auxiliary building per construction is used for the storage of radioactive contaminated liquid and solid waste generated in water purification equipment and in the controlled zone, as well as for the reception of technological systems related to waste management. The auxiliary buildings are connected to the main buildings by a bridge and a tunnel, they are also connected to each other by a pipe bridge, which is used for the transport of liquid waste.
- Diesel generator buildings: In the two diesel generator buildings, 6-6 diesel generator units have been installed, which is the source of electrical feed-in to the safety 6 kV distributors of the NPP in a given emergency situation.
- Emergency diesel engine rooms: In the northern and southern accident diesel engine rooms, 1-1 diesel generator unit was installed to supply electricity to the mechanical, electrical and control systems involved in accident management in the event of an accident in the NPP's systems.
- Sanitary and laboratory building: The building was built to serve the units 1-4. It is located between the two principal operational building, connected to them by a two-storey transport bridge, on which the passenger traffic between the changing rooms and the workplaces in the main building, as well as the light freight traffic are handled. In fact, the complex installation acts as a ‘lock’ between the controlled zone and the operational area. In the controlled zone of the building there are the primary circuit changing rooms, washrooms, showers, laundry facilities, the Dosimetry Service, the control rooms of the radiation protection control system, as well as the radiochemical, release control and material testing laboratories.
- Chemical and makeup water preparation room: The building is used for the production of demineralized water necessary for its operation, as well as for the installation of technological and service systems that provide the primary and the secondary circuit chemical needs. A technological outer tank park was established in the courtyard. The technological connections are made through pipe bridges and reinforced concrete technological channels.
- Water intake structure, water control room: The water intake structures providing the power plant's water supply are divided into three units. Separate water intake structures belong to the units 1-2 and units 3-4. For the two water intake structures a joint control building was built, which was built for the equipment performing the operation, monitoring and control tasks of the electrical equipment. The two pumping stations at the end of the cold-water channel takes out the required amount of condenser and safety cooling-water. Safety cooling-water is delivered directly to consumers; condenser cooling-water is delivered to the raw water pool on the pressure side of the pumping plant. Mechanical equipment and raw and filtered water storage pools are located in a filter room where also the filtered raw water pools are located.
- Weir with level-control function: Its task is to provide the water level necessary for the gravitational operation of cooling-water traffic and to provide the possibility of warm water recirculation into the cold-water channel. The structure with reinforced concrete is located

in the warm-water channel between its part of closed section with reinforced concrete and its part of open section with earth bed.



1. I. Principal operational building (0001)
2. II: Principal operational building (0201)
3. Sanitary and laboratory building (0007)
4. Auxiliary building, I (0002)
5. II. Auxiliary building (0202)
6. Diesel engine room I (0004)
7. Diesel engine room II (0204
8. Chemical water preparation room (0008) and make-up water preparation room (0033)
9. Hydrogen and nitrogen tank park
10. Hydrogen operation building (0005)
11. I-II. Water intake structures (0023-0223)
12. Sewage treatment facility
13. Southern emergency diesel engine room (0130)
14. Northern emergency diesel engine room (0230)

Figure 2.2.1.2-3. The important buildings and structures at the Paks NPP site

- Warm-water channel: Its task is to drain the cooling water heated up during the operation of the power plant into the receiver, the Danube. The warm-water channel is partly provided by a closed-section reinforced concrete canal with a ‘weir’ built with twin sections, and by a paved, open-section channel connected to it. The warm-water channel connects to the Danube with an energy-breaking structure.
- Warm-water recirculation system: Before the estuary of the warm-water channel, the recirculation system, which ensures the de-icing of the cold-water channel and the replenishment of water in incident event, branches off from the channel. The purpose of warm-water recirculation is to de-ice the bay area in front of the pumps of the water intake plant during the winter period, and to replenish water in the event of low water levels on the

Danube, similar to the warm water recirculation system for incident events. The warm-water recirculation system for incident events (2 steel pipelines starting from the warm-water channel and connecting to the cold-water channel) was established for operation in the event of low water levels or permanently low temperatures on the Danube. However, the practical function of the system is limited to de-icing (and optimizing the use of water resources). However, it is not used for water replenishment in case of low water levels, other solutions (using pumps) are used for this purpose.

- Unit ventilation chimneys: Ventilation chimneys are responsible for the emission of filtered air from the power plant' primary circuit rooms transmitted by ventilation systems. To serve the units 1-2 and units 3-4, a twin ventilation chimney with a height of 100 m and reinforced concrete structure was built. Both chimneys are twin chimneys with natural draught.
- Hydrogen and nitrogen tank park: Its task is to store the hydrogen gas arriving in the tanker for cooling the generator, as well as the nitrogen gas for emergency draining of the generator, for displacing the primary circuit technology from the system and for servicing the measuring systems in liquid and air form. In the event of failure of the tanks installed for the storage of 15 gaseous hydrogen and 10 gaseous and 4 liquid nitrogen, the protection of the on-site technological facilities and offices is ensured by reinforced concrete walls.

2.2.1.3. Related activities and facilities

2.2.1.3.1. Water supply, wastewater treatment

Water use, water supply

Based on the function, the water use of the facility can be divided into two main groups:

- For cooling purposes, the power plant draws water from the Danube through the open cold-water channel, which, after use, is fully returned to the Danube as a receiver through the open section warm-water channel.
- The industrial water used to replace the power plant technological water losses comes from the Danube abstraction, the source of the fire water is the bank-filtered well-yard (with warm-water channel reserve), and the source of the drinking water and utility water is the well-yard with 9 deep-drilled wells at Csámpa (layer water).

The annual water demand is 2.9 billion m^3/year from surface water abstraction and 200,000 m^3/year from water wells. The theoretical water demand of the main circulating water system is 25 m^3/s for one reactor unit, the theoretical water demand of the simultaneous operation of four units: 100 m^3/s (360,000 m^3/h). The units 1-4 have a water demand of 2.5-3.1 billion m^3/year, which also includes a safety water demand of 72 million m^3/year. The quantity of quota used per year is influenced by the reduction effect of maintenance stoppages and recirculation.

Communal sewage treatment and disposal

A sewerage network system is in operation in the Paks NPP area. The receiver and purifier of the power plant's communal sewage, the sewage of the sanitary and laboratory building and occasionally the over-balance water is the domestic sewage treatment plant with a capacity of 1,870 m^3/day. The sewage treatment plant consists of 2 blocks of TABTA-type structure lines. In both structure lines, the treatment technology is a complete biological treatment with activated sludge in the mechanical and total oxidation ranges. The excess sludge is placed on sludge-drying beds.

The structure line I (670 m^3/day) uses surface air intake devices (rotors) to ensure adequate oxygen concentration in the pools. Sludge pre-circulation is automatically ensured by the suction effect of the rotors. The structure line II (1,200 m^3/day) has a deep air blowing system. 1 Jet aerator in the pre-aeration pool, 1+1 Jet aerators in the aeration reservoir pool, and fine bubble deep air in the aeration pools ensure proper oxygen concentration and mixing of the mixture. The aeration pools are equipped with 2+2 sludge units and pumps for sludge pre-circulation.

The modernized structure line II is operational; the structure line I is a backup. The power plant shall notify the water authority of the entry into operation of the reserve structure line I.

The treated sewage drained from the domestic sewage treatment plant is connected to the warm-water channel via a steel pipeline right in front of the energy-breaking structure. Before introduction into the canal, there is a sampling shaft, which is a sampling site V3 of the power plant.

The excess sludge from the re-settler is transferred to a sludge thickener, where the sludge water and the sludge are separated. The compression time is 4-6 hours. The compressed sludge is transported through the sludge line to sludge bed with a surface of 1,200-1,300 m^2 for further dewatering. Dehydrated sludge is disposed of after checking the radioactive concentration, depending on the result. If it does not have to be treated as radioactive waste, it is classified as hazardous waste and is disposed of in accordance with the legislation on hazardous waste.

Industrial sewage treatment and disposal

Wastewater from the re-rinsing of filters installed at the water intake, waste removed with water at the grebe cleaners and other wastewater from the water intake operation shall be received by the warm-water channel section located immediately after the fall.

The treatment of wastewater from the water softener is part of the industrial sludge system of the machine. Its task is to receive and purify chemical sewage and discharge purified water into the receiver. Treatment of sewage from a water softener is carried out in two steps. The first step consists of spontaneous neutralization in the suction shaft of the pump. The second stage is the tailings pond, which performs the tasks of phase separation and settling. The 2 pcs 10,000 m^3 tailings ponds are used for the treatment and sedimentation of wastewater from the water softening equipment. The treated (purified) water is gravitationally discharged from the mud basin through an overflow into the warm-water channel. Monitoring wells have been set up in the surroundings of the tailings area to monitor leakage and groundwater quality.

Technology wastewaters containing oil

Oily sewages are treated at their source. In the case of car washer, the treated sewage is discharged into the domestic sewage system of the power plant, in the case of the other generation sites (fire pit car washer, oil storage barrel tank, truck washer) after proper treatment is discharged into the industrial storm drains sewerage network of the power plant.

Rainwater drainage

The rainwater pipelines and canals lead the roof water of the buildings and the rainwater collected from the roads and green areas to the belt ditches located in the outside of the power plant. There are 5 main collecting rainwater drainage in the Paks NPP area. The industrial storm drains sewerage network within the plant is connected to the belt canal system outside the plant area. The receiver of rainwater transported by the northern belt canal is the cold-water channel, while the receiver of rainwater canaled into the southern belt canal is the warm-water channel.

2.2.1.3.2. Carriage of freight and passengers required for the activity

The site can be reached by road from the north and south direction from the Main Road No. 6, from which a branch (north and south entrance) leads to the power plant area (*Figure 2.2.1.3.2-1.*). The site can also be accessed from the southern direction, from the Paks-Gerjen connecting road, which connects to the southern entrance road of the power plant. The site can be accessed from the Motorway M6 at the 113 km section at the junction Paks South and continuing on the road No. 6232 then touching the area of Paks city (Kölesdi út – Dankó Pista utca), and then going to the section of the Main Road No. 6 below the Paks city from the north. From the railway terminus Paks, only target trains can reach the power plant's site via the siding only with the aim of freight transport, and no passenger transport is carried out by rail. The spent fuel assemblies to be stored at the SFISF arrive at the SFISF site from the NPP on a railway train towed by a diesel locomotive. Fuel delivery takes place 10-12 times a year, each delivery lasts up to a few hours. Rail transport is therefore ad hoc and negligible in terms of its environmental impact.

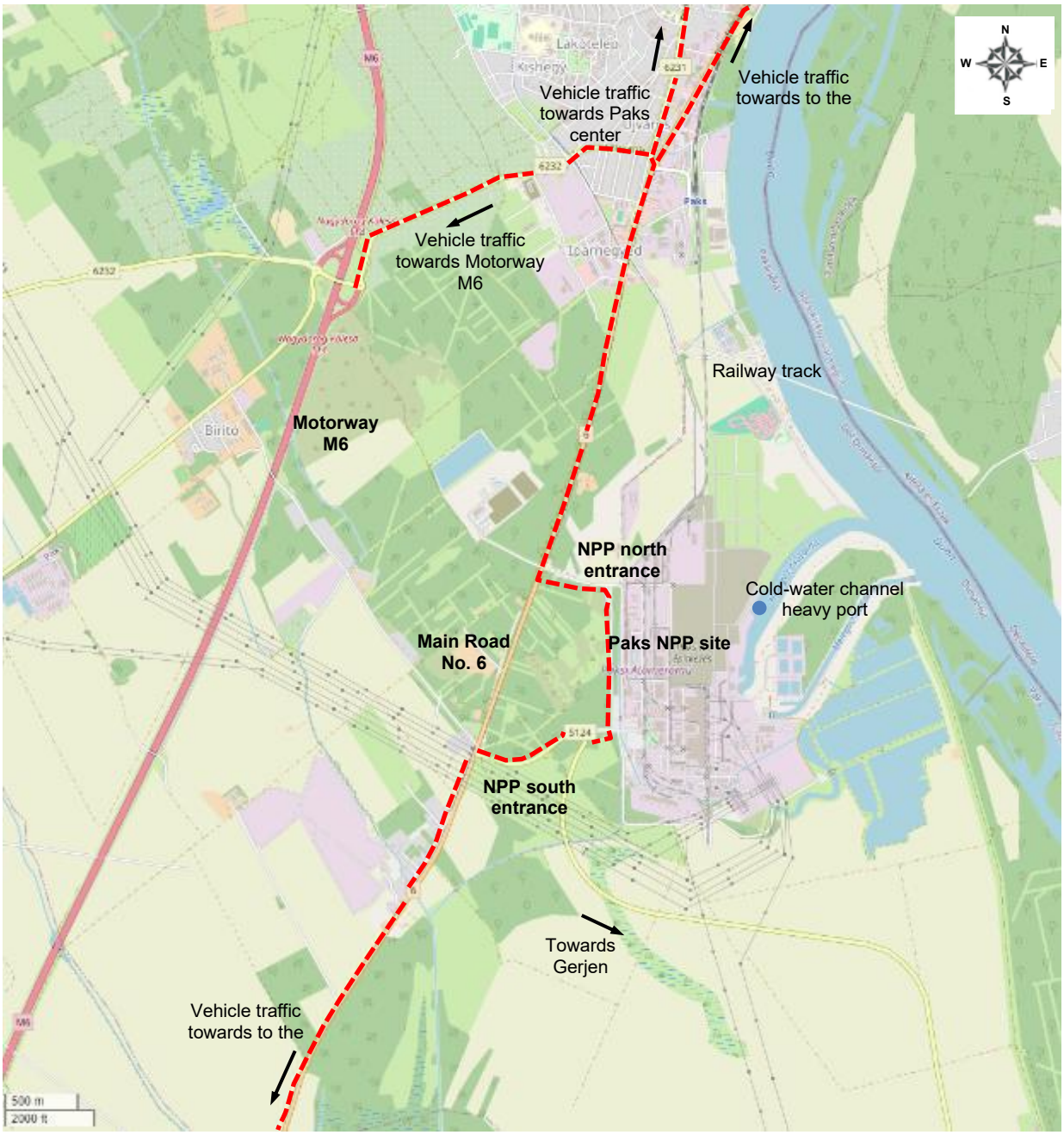


Figure 2.2.1.3.2-1. Access routes to the power plant site

The power plant site is accessible by water, the cold-water channel has a heavy port. Transport on water is also occasional, exclusively for freight transport, with a negligible volume in terms of environmental impact. The transport routes shown in the *Figure 2.2.1.3.2-1.* were used to determine the volume of operational freight and passenger transport concerning the Paks NPP operation. Passenger and freight transport concerning the power plant is essentially carried out by road. Taking into account the available on-site entry data regarding the NPP site, for the number and type of vehicles, the typical daily occupancy of the on-site car parks and public transport bus traffic, the road traffic related to the operation of the Paks NPP can be characterized by the data listed in *Table 2.2.1.3.2-1.*

One round per day, i.e. arrival at the power plant and passing from the site after a stay of different durations, may be taken into account for the given number of vehicle pieces. Vehicles entering and leaving the power plant are assumed to travel in the north by about 2/3, and in the south by about 1/3, with about 10% of vehicle traffic going to the Motorway M6 and 90% remaining on Main Road No. 6.

There is no significant change in existing freight and passenger transport needs related to operation of the power plant during the Paks NPP SSLE period. Considering that the supply of the materials, devices and other goods used in the NPP can still be considered as the frequency and volume currently experienced, and no significant change in the number of operators and maintenance personnel can be forecast for the future, the volume of freight and passenger transport related to the activity can be estimated to be the same as at present for the SSLE period as well.

However, due to the modifications planned in the context of the preparation of the SSLE, in particular the development of an alternative warm-water channel and the connected peak cooling system, a periodic increase in the volume of freight and passenger transport (construction materials, construction personnel) to the site is expected. The construction works and the estimated increase in traffic related to them are presented in *Chapter 2.2.2.1.*

Table 2.2.1.3.2-1. Road traffic relating to the operation of the Paks NPP

Vehicle type	Average daily traffic* [vehicle/day]		
	Day	Night	Total
Freight transport traffic			
Average daily truck traffic (typically van)	450	40	490
Passenger traffic			
Passenger car	1,920	220	2,140
Bus	316	58	374
Motorbike	90	–**	90

* The number of vehicles were determined by means of simplifications in favour of overestimation.
** It's negligible.

2.2.1.3.3. Other related activities, technological systems

There are many technological systems in the NPP which, according to their safety classification, do not affect nuclear safety or are not directly related to production. These systems are necessary for the general operation of the power plant. The listed systems are responsible for the handling, transport and storage of hazardous substances and conventional hazardous waste, so in the event of their failure there is a possibility of environmental pollution. These are the followings:

- industrial wastewater collection, lifting and drainage system,
- industrial tailings area (lime sludge, chemical pools),
- chemical detoxification and special chemical preparation,
- chemical transfer and dosing systems,
- chemical wastewater discharge lines,
- turbine oil system,
- oil depletion station and emergency discharge system,
- engine and main feedwater pump oil system,
- safety diesel generator lubrication oil, waste oil and gas oil system,
- domestic sewage network,
- chemical storage.

2.2.1.4. Condition-maintenance and ageing management system

Based on the requirements set out in Volume 2 *"Management systems of facilities"* of the Nuclear Safety Code (NSC), the management system of the MVM Paksi Atomerőmű Zrt. covers the entire operation of the NPP, thus it also covers the activities necessary for the implementation of the maintenance, testing and supervision program. The related activities are organized into processes, the method of implementation of the processes is described in the policies. Based on the requirements of the management system, the procedures developed and applied are regularly reviewed and validated on the basis of operational experience and expected results.

As part of the operation of the NPP units, the NPP operates a comprehensive work planning and management system in order to perform the tasks related to the maintenance, testing and supervision program to be carried out on the unit during operation and major overhaul. The operational processes of the work planning and management system, as well as the processes of the supply chain, are included in the main process of work management. The main process covers the preparation of the medium-term major overhaul plan, the planning of the given unit's major overhaul, as well as the operational management of the facility works, from work ordering, work prioritization, work planning, security assessment to the cyclical implementation of the programs defined by state-related interventions, standards, manufacturing or internal regulations, and the implementation of sudden repair and preservation tasks. The main work management process also includes a system of material and service planning and monitoring necessary for the execution of the works, in order to ensure that all tasks are carried out with the appropriate urgency according to their priority, and that no shortage of materials or resources arises. The main process implements feedback through a workweek and major overhaul evaluation in order to continuously improve the performance.

The determining elements of the maintenance system are the monitoring of the efficiency of the maintenance program, the evaluation of the achievement of the maintenance objectives set, and thus the verification and correction of the efficiency of the program, if necessary.

The program has a decisive technical influence on the management and execution of operational tasks and on the technical decision-making mechanism for interventions following unplanned events on the technological equipment and systems of the power plant.

Equipment-level lifecycle management means the operation of a complex management practice, in which the management of the NPP ensures that equipment with safety relevance and function is available during the entire service lifetime with the required performance parameters.

The identification, professional content and everyday practical implementation of the current requirements for the NPP systems' technical condition maintenance system are summarized and described in the basic technical document of the system up-to-date.

In order to meet the condition maintenance objectives, the established structure designs and technically prepares the management of ageing processes, the medium-term and annual maintenance programs, as well as the preventive maintenance, testing and monitoring program to ensure that the systems and system components retain their characteristics in line with the design requirements. Schedule and prepare technical reviews, condition monitoring activities, determine the technical content and timing of refurbishment and replacements.

An aging management system was developed and operates in the NPP. During the elaboration of the ageing management program, all deterioration mechanisms were identified for safety-relevant equipment. The aging management program is aligned with the maintenance processes, qualification procedures of the system components.

Environmental conditions, process conditions, operating cycles, maintenance plans, planned service lifetime and test schedules were taken into account when establishing and operating the comprehensive ageing management program.

The aging management process of the Paks NPP includes measures that are necessary to prevent and detect the development of aging mechanisms. For the assessment of ageing effects, the operator shall carry out monitoring, testing, sampling and control activities that ensure the timely identification of unforeseen processes or deteriorations during operation and the necessary preventive and corrective actions. The system of periodic inspections applied in the NPP meets the requirements of ASME Boiler & Pressure Vessel Code, Section XI: In-service Inspection of NPP Components, version 2001 of which is published as Hungarian standard (MSZ 27011).

Maintaining the technically correct condition does not require any special preparation, since the comprehensive aging management program is constantly updated to ensure the reliable and safe continuous operation of the power plant.

On the basis of the above, it can be concluded that the condition of the equipment and buildings in the Paks NPP is continuously monitored as part of the operation, the necessary maintenance

and refurbishment are carried out as planned, which activities provide the basis for maintaining the expected technical condition of the NPP, and thus the feasibility of the SSLE.

2.2.2. Preparing for the SSLE, planned activities, transformations to the subsequent operation

Based on the results of the technical analyses and feasibility studies related to the preparation of the SSLE, the MVM Paksi Atomerőmű Zrt. plans to implement the following technical and technological modifications, which have been analysed and evaluated in terms of the nature and significance of the expected environmental impacts and the need for a detailed assessment of the impacts:

- implementation of an alternative warm-water channel and peak cooling system,
- installation of emergency replacement safety diesel generator in units 1-2.
- diversification of fuel purchases of the NPP,
- modification of spent fuel management,
- other planned reconstructions, measures, interventions.

2.2.2.1. Designing of an alternative warm-water channel and peak cooling system

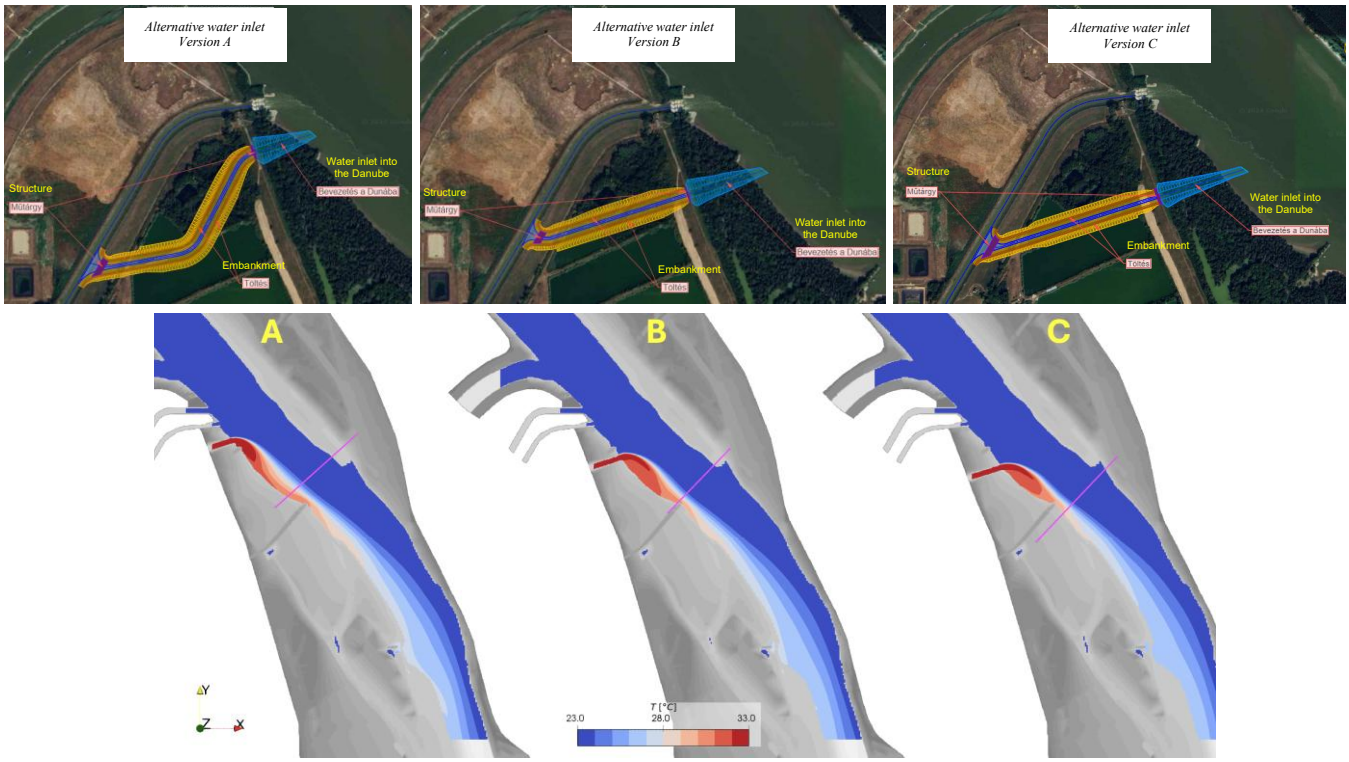
The final heat removal of the technological systems of the Paks NPP is carried out by cooling with fresh water from the Danube. To the power plant installed on the right bank of the Danube, the water is routed to the units through a dedicated cold-water channel, and then the water warmed by the technology is returned to the Danube through the warm-water channel. According to the limit on the thermal load of the Danube laid down in the legislation, a maximum temperature of 30°C is allowed at 500 m downstream of the discharge point at the entire cross section. Compliance with the prescribed temperature limit can currently be ensured by reducing the electrical power of the power plant to the necessary extent during critical periods, which does not affect the maintenance of nuclear safety, but on the one hand it results a loss of production in the NPP's electricity production, and on the other hand it poses an energy supply risk for the national electricity system.

In the future, climate change alone is expected to increase the prevalence of periods where – with the current heat dissipation system – increasingly large and frequently load reductions would be required to comply with the 30°C limit. In addition, the entry into operation of the new units in Paks (Paks II NPP) will further increase the number and extent of the required backload.

Following the decision on the SSLE of the Paks NPP units, the above circumstances necessitated the examination of measures and technical solutions to ensure the long-term observance of the heat load limit. The aim of the examination carried out was to examine technical solutions ensuring the relocation of the current inlet point of the warmed cooling water into the Danube further south. With this new inlet point – further away from the planned warm water inlet point of the Paks II NPP, the mixing conditions of the warmed cooling water plume originating from the two power plants can be made more favorable. In addition, the aim of the examination was to determine how the cooling of the warmed cooling water of the Paks NPP before its return to the Danube can be achieved using artificial cooling systems.

The new inlet point was determined in two phases, the first of which took into account alternatives that would be implemented at slightly greater distances from the current inlet point. However, these solutions were rejected due to less favorable results and conditions.

The detailed analysis of the optimal location of the alternative water inlet point in the second phase – taking into account the location of the corresponding 500 m reference section – was carried out for three versions, located south of the current inlet point, within a distance of approximately 350 m. In the case of all three examined versions (“A”, “B” and “C”), the new water inlet can be implemented by construction an alternative warm-water channel section branching off from the existing warm-water channel, as shown in *Figure 2.2.2.1-1.* To evaluate each water return point, heat transfer model calculations were performed to determine which return point provides the most favorable results in terms of heat plume mixing.



The 500 m reference section for each warm water inlet point is indicated by a solid magenta line in the lower figures.

Figure 2.2.2.1-1. The alternative warmt water inlet locations examined (versions "A," "B," and "C") and the results of the heat propagation model calculations for them

Based on the results of the calculations, among the alternative return points examined, the one marked "C" is clearly the most favorable in terms of heat plume mixing, and in fact, in terms of actual maximum water temperatures, it provides significantly more favorable conditions than the current state. In this case, the 500 m reference section belonging to the inlet point falls on the downstream side of Large spur, located approximately 800 m downstream from the current introduction point. The high turbulence at the nose of the spur has a significant mixing effect, which has been demonstrated in previous studies using both field measurements and numerical modeling tools.

The additional cooling system (peak cooling system) can be installed in the area between the existing and the new channel sections. Its task is to reduce the temperature of the Danube water used for cooling purposes in the NPP, which has thus warmed up, before it is returned to the river. As a result of operating the cooling system, the extent and duration of the power reduction of the power plant, which is required due to Danube thermal load limitations, can be reduced.

In international practice, the most common artificial cooling solution combined with fresh water cooling for nuclear power plants is the use of artificial draft wet coolers (cooling cells). The peak cooling system to be installed for the Paks II NPP was also designed with this technology. Accordingly, cooling cells were also considered in the case of the Paks NPP for cooling the heated cooling water before it is returned to the Danube. Due to its modular structure, the cooling system consisting of cooling cells can be designed with the required capacity (number of cells) and a layout that can be adapted to the available space. When selecting the cooling technology – with regard to operation and maintenance aspects – it was an important consideration that a cooling system with the same technology and similar design as the one planned next to the warm-water channel of the Paks II NPP would be implemented.

Based on the results of the analyses carried out taking into account the above versions, the MVM Paksi Atomerőmű Zrt. plans to implement the alternative warm-water channel section branching out from the existing warm-water channel and the related peak cooling system version "C", consisting of cooling cells, with the aim of:

- the possibility of limiting the temperature of the warmed water to be discharged to the Danube during joint operation with Paks II, in accordance with environmental conditions,
- the protection of the Danube ecosystem by limiting the maximum discharge temperature,
- reduce the backload and the number of backloads due to the high-water temperature of the Danube to a minimum,
- ensuring the possibility of reconstructing the existing energy-breaking structure.

The route of the planned alternative warm-water channel section branches out from the existing warm-water channel on its right bank, following the canal pumping station (*Figure 2.2.2.1-2).* The new channel section of about 950 m will be constructed in the same way as the existing warm-water channel, with a bottom level of 90.2-90.5 mBSl and a 20 m bottom width channel with a 1:2 slope on both sides, covered with reinforced concrete. At the inlet to the Danube of the new warm-water channel section, an energy-breaking structure complemented by an energy-dissipating basin will be built, with a similar design to the one in the existing warm-water channel.

The track of the new warm-water channel section reaches the Tolnai Duna Natura 2000 area using 2.1 ha of land on the floodplain between the flood protection embankment and the Danube, and crosses the forest area No. 306/A registered as forest sections in the National Forestry Database and the core areas and ecological corridor areas belonging to the National Ecological Network, by crossing them (*Figure 2.2.2.1-2).* The new channel section also affects the northern areas of the existing fishponds with an area of about 5 ha.

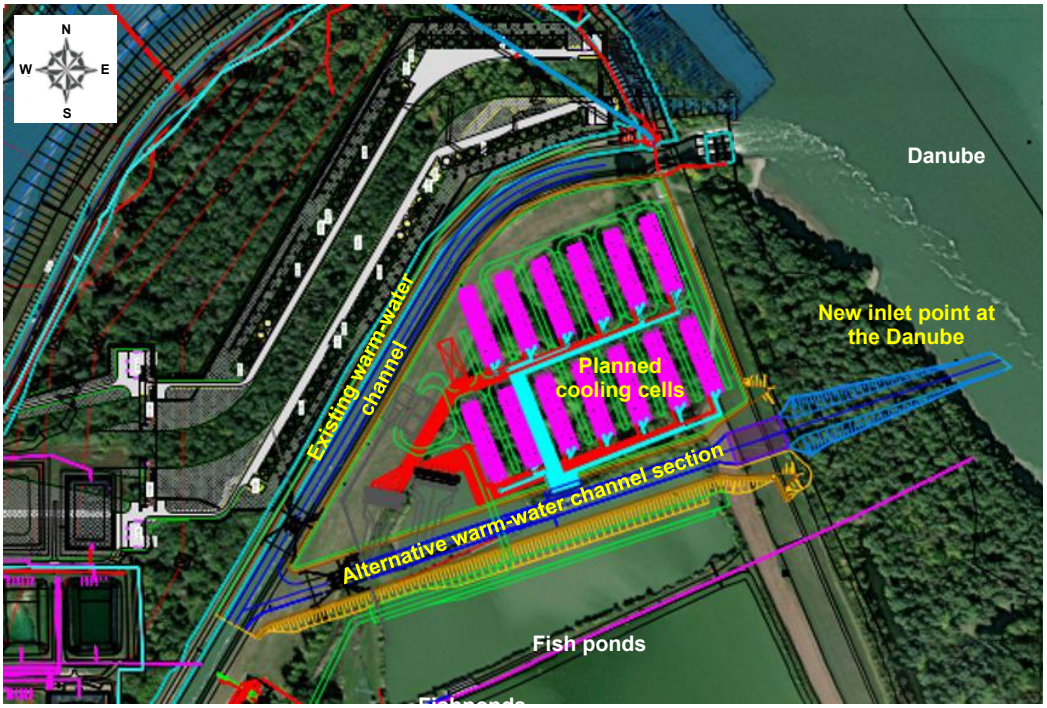


Figure 2.2.2.1-2. Layout of the alternative warm-water channel section and the connected peak cooling system

The cooling cells and their connected technological auxiliary systems (pumping station and pipeline network, electricity supply equipment and structures, internal road network, public utilities) will be located in the area between the existing and new channel sections. The area between the existing and the new channel section will be replenished to a level of approximately 97.0 mBSl, for which the currently existing vegetation of approximately 8 ha in the area will have to be removed. To replenish the area, about 700,000 m^3 earth material is required.

The pumping station for the cooling systems will be built on the left bank of the new channel section. In the section between the energy-breaking structure and the pumping station, a levelling structure is installed in the bed of the new warm-water channel. For the proper water level control of the upper section of the channel, a weir with level-control function is designed. The pumping

station installed on the new warm-water channel (structure, mechanical and electrical systems) lifts the warmed water onto the flow-type wet cooling cells.

Water pumped from the alternative warm-water channel section enters the cooling cells, where the water to be cooled is broken into small droplets using nozzles and the so-called droplet-forming insert, thereby creating a large heat-dissipating surface. The falling droplets transfer their heat to the air flowing through them and cool down in the process. The air flow is provided by a fan located on the top of the cooling cell. Heat removal occurs at the droplet surface by sensible heat transfer and evaporation (latent heat transfer). Wet cooling can cool water even if the ambient air temperature is higher than the temperature of the water to be cooled. In this case, heat removal is entirely based on evaporation. In this case, the energy required for evaporation (heat of vaporization) comes from the water's own internal energy, which lowers the temperature of the water droplet.

The cooled water droplets fall into the basin below the cells, from where the collected, cooled water flows back into the channel by gravity, in the section after the level-control weir.

It is planned that 78 artificial draft cooling cells will be installed in the area enclosed by the two warm-water channel sections, arranged in 13 cell rows. The size of a cooling cell is 16.8x16.8 m, its height is 15 m.

The planned investment also includes the construction of a new solid paved road with a length of approximately 400 m and an operational bridge over the new canal section.

The artificial elements necessary for the implementation of the alternative warm-water channel section and the connected peak cooling system are as follows:

- a reinforced concrete channel of approximately 950 m in length,
- hydro-construction structures:
  - (bed closing) dams with tilting boards,
  - weir with level-control function,
  - energy-breaking structure complemented by an energy-dissipating basin,
  - pumping station installed on the alternative warm-water channel section,
- 78 artificial cooling cells in 13 rows of cells,
- other elements (solid paved road, operational bridge).

The construction of the alternative warm-water channel section and the related structures, as well as the preparation of the site for the installation of the cooling system's structures, includes the following construction work phases:

- Delimination, construction of work areas (approximately an area of 20 ha), access, construction of side roads to the site. Required machinery, transport vehicles: trucks, semi-trailers, mobile cranes, front loaders, pusher dozers, road rollers, sprinklers.
- The harvesting and removal of existing vegetation on the area enclosed by the existing and new channel section (approximately 8 ha), and the harvesting and existing vegetation on the affected floodplain forest area (Natura 2000 area) to the extent necessary (2,1 ha) and its removal. Required machinery, transport vehicles: logging machine, hand saw, loader crane truck.
- Earthworks:
  - replenishment of the area between the existing and the new channel section up to 97.0 mBSl, which requires earth material of 700,000 $m^{3,}$
  - embankment construction, which requires earth material of 300,000 m^3,
  - dredging in the volume of 50,000 m^3, the dredging material from the floodplain can be used for the salvaged side earthworks.

  Required machinery, transport vehicles: the simultaneous operation of up to 3 machine chains is assumed, with a chain of excavators, dozers, cylinders, scrapers, food plainer (grader) and a sufficient number of means of transport.

- Construction of the channel, structures, road and bridges:
  The construction of the channel coverings requires the supply and installation of building materials of 20,000 m^3, and the construction of the floodplain stone structures requires the supply and installation of stone materials of 20,000 m^3. The construction of hydraulic engineering structures requires the supply and installation of cement, gravel (or finished concrete), as well as the supply and installation of other building materials, mechanical and electrical equipment to be installed. Concrete of 10,000 m^3 is required for the construction of an energy-breaking structure. A solid paved road with a length of 400 m and an operational bridge will be built through the new channel section. The construction works end with landscaping and the reforestation of the land structures.

  Required machinery, transport vehicles: trucks for the transport of cement, gravel and other materials and equipment, mobile cranes, shovel grabs, concrete mixers, concrete pumps, hoists and loaders.

During the construction of the above-mentioned earthworks, the channel and the related structures, the soil excavated from the affected area will remain within the construction area and will be used locally. In order to fill the area and build the embankment, additional earth material must be delivered to the construction site in the quantities specified above.

The total time required to complete the above work phases is 2 years, night work is not planned. No demolition work is required for canal construction.

With the establishment of the alternative warm-water channel section, a new Danube warm water inlet point will be created, thus the reference profile of the temperature limit prescribed by the legislation on heat load will also be reduced by approximately 350 m compared to the current one. By closing the bed blocking structure to be installed in the existing warm-water channel, the total amount of warmed water to be returned to the Danube can be routed to the alternative channel section.

The operation of the alternative warm-water channel section and the related structures involve checking the condition of the structures, the necessary repairs and maintenance. In the case of embankment and unbuilt areas, regular (twice a year) mechanical mowing, small-scale excavation work (1-2 off-road vehicles or vans per day, 4-5 people working in the affected areas) can be taken into account during the daytime period.

The periodical inspection of the embankment and the structures is carried out mainly by visual inspection (on-site access along the route e.g. every 2-3 months, if necessary movement /sinking, displacement / instrumental control /geodetic survey / e.g. every 2-3 years), related to which: 1 off-road vehicle; car, or van a day, the work of 2-3 people along the embankment and in the surroundings of the structures can be taken into account during the daytime. During the flooding period, it is necessary to ensure constant supervision with 2-3 people, 1-2 cars per day. Minor maintenance every 3-5 years, major maintenance every 10 years, repair of structures as needed (refurbishment, replacement of spare parts, corrosion protection works, painting, etc.)

The steel structure of the cooling cells is built by leaning on the concrete pool receiving the cooled water, which holds the ventilator providing the artificial draught. The water to be cooled is delivered by pipelines from the pumping station to the upper part of the cooling cell. Due to the large size of the cooling cells, the steel structure and the associated equipment and structural elements (electric motors, ventilators, cooler inserts, casings, pipelines, electric cables, fittings) are assembled and installed on site. The supply of construction and structural materials, spare parts, etc. is planned with road freight vehicles according to the schedule of each work phase.

The construction work phases for the construction of cooling cell system structures and related mechanical and electrical equipment are as follows:

- Delimitation, construction, access of work areas. Required machinery, transport vehicles: lorry, semi-trailer, mobile crane.
- Earthworks, foundation-concrete pool construction:
  - The concrete pool of the cooling cells is made with a basement depth of about 1.5 m according to the size of the cell units of 16.8x16.8 m (when draining water from the pool,

a depth of about 2.5 m should be taken into account). After digging the base pit, the concrete pool is built, with the necessary pipeline outlets.
  - Concrete pool construction can be carried out on the whole area at several rows of cells, on 3-4 working areas in parallel, e.g. with a 1-month delay.
  - The duration of earthwork on each working area is about 1 month, the duration of reinforcement-concrete is approximately 2-3 weeks, the solidification of concrete is 1 month, the duration of pipeline assembly requires 2 months, the estimated duration of the entire working phase is about 4.5 months.
  - The supply of construction materials and the transport of construction personnel is assumed by road vehicles.
    Required machinery, transport vehicles: bucket excavator, front loader, car crane, concrete mixer, concrete pump, hand tools, truck, semi-trailer.
- Structural construction:
  - The steel structure of the cooling cells is built and assembled on site, typically with hand tools (welding, screwing), in the case of a row of cells for a period of about 1-1.5 months. Structural construction can be carried out on the whole area at several rows of cells, on 3-4 working areas in parallel, e.g. with a 1-month delay.
  - Installation of cooling cell inserts, installation of casings with characteristics similar to those given for steel construction.
  - The supply of structural materials and the transport of construction personnel is assumed by road vehicles.
    Required machinery, transport vehicles: mobile cranes with different lifting heights, truck with basket lifting machine, hand tools (welding machine, metal cutting machine, screwdriver), truck, semi-trailer.
- Mechanical and electrical installation:
  - Installation of ventilators, electric motors, pipelines, cabling, installation of electrical fittings, which is typically carried out with hand tools, for a period of 1-1.5 months.
  - The supply of spare parts, installation materials and the transport of construction personnel is assumed by road vehicles.
    Required machinery, transport vehicles: car cranes, truck-mounted basket lifters, hand tools, trucks, semi-trailers.

The total duration of the construction of the cooling cells colling system depends on the number of cooling cells and the number of workplaces created in parallel. With parallel work in 3-4 workspaces, the entire system can be built in about 1.5 years. No demolition work is required to build the cooling cells.

The schedule for the construction of the alternative warm-water channel and peak cooling system is presented in *Table 2.2.2.1-1.* Based on the estimated durations for the completion of the work phases in the table, it can be seen that the construction of the alternative warm-water channel and peak cooling system is expected to take nearly 3.5 years.

The construction works of Units 5-6 of Paks II NPP are currently underway, the slurry walling and soil improvement in the area of Unit 5 have been completed, the concreting of the base plate is in progress. The construction of the working pit (earth raising) in the area of Unit 6 is in progress. The expected duration of the construction and installation works (main construction period) of Units 5-6 – following the deepening of the working pit and soil improvement – is nearly 6 years. Large-scale structural construction works (construction of buildings, structures) with significant environmental impacts are expected in the first half of this period. After the construction of the building structures, technological installation work within the building begins (installation of mechanical, electrical, and instrumentation and control systems), followed by the gradual commissioning of the individual completed systems, carried out in parallel, partly overlapping with the construction and installation activities.

After the completion of the main construction period, the new units will be commissioned and the subsequent test run will take place. Taking into account the latter's regulatory approval and the time of the test run, as well as the fact that the test run of Unit 5 is planned to be followed by the test run of Unit 6 with a one-year delay, the period when significant environmental impacts related to the construction of the new units no longer need to be considered may be 3-4 years.

The construction of the alternative warm-water channel and peak cooling system – lasting nearly 3.5 years – was planned in parallel with the nearly 6-year main construction period of the Paks II NPP. By the expected duration of the construction works of the channel and the peak cooling system, the large-scale structural construction phases of Paks II NPP, which have significant environmental impacts (foundation, construction of buildings, structures, roads) are expected to be completed. In parallel with the construction of the channel and the cooling system, technological installation works (installation of mechanical, electrical, instrumantation and control equipment, assembly of stands, pipelines, cabling) will typically take place within the already structurally completed buildings in the Paks II NPP construction area, the environmental impact of which is significantly more moderate, therefore, when added to the impacts of the earthworks of channel construction, they do not represent a significant surplus. During the parallel construction period, the environmental impacts associated with the construction of the channel and the cooling system will therefore be the determining factors. The cumulative impacts of the two construction activities as described above can be characterized by the impacts resulting from the most intensive period of channel construction, in respect of which the EIA of the SSLE covers the impatcs on the affected environmental elements and systems.

Table 2.2.2.1-1. Planned schedule for the construction of the alternative warm-water channel and peak cooling system

Activity	Duration [months]
I. Construction of the alternative warm-water channel section and the related structures	
Delimination, construction of work areas, site mobilisation, construction of access roads	0.5
The harvesting and removal of vegetation on the areas afected with the construction	1
Earthworks (replenishment of the construction area, embankment construction, floodplain dredging	10.5
Construction of the channel, structures and bridge	12
Total construction duration (I):	*24 (2 years)*
II. Construction of the cooling cell cooling system structures and the related mechanical and electrical equipment	
Delimination, construction of work areas, site mobilisation	0.5
Earthworks, foundation-concrete pool construction	4.5
Structural construction (construction and assembly the of steel structure of the cooling cells)	10
Mechanical and electrical installation	7 (in parallel with the construction of the structure) 3 (after the construction of the structure)
Total construction duration (II):	*18 (1.5 years)*
Total construction duration of the alternative warm-water channel and peak cooling system (I+II):	*42 (3.5 years)*

Based on the schedules presented above, the construction works of the alternative warm-water channel and peak cooling system can be carried out in parallel with the main construction period of the Paks II NPP, until the new power plant units are ready for commissioning.

Linking the commissioning deadline of the new, alternative warm-water channel and peak cooling system of the Paks NPP with the commissioning deadline of the new units provides a relative scheduling opportunity for the implementation of the alternative warm-water channel and peak cooling system, and also provides sufficient reserve time if the planned schedule is delayed due to unforeseen reasons.

Operation of cooling cells shall be phased and shall take place only in justified cases during specified periods of the year. During the operation of the cooling cell system, chemical treatment (anti-corrosion, anti-calculation, biocide) of the water entering the cooler system is not necessary, therefore, no chemicals resulting from the cooling cell system operation may enter the water returned to the Danube. After the end of the operating period, the surfaces are cleaned with high-pressure washing.

The operation of the cooling cell system includes the monitoring of the condition of structures, mechanical and electrical equipment, as well as the necessary repairs and maintenance. Regarding the fact that the equipment is not running continuously, repairs and maintenance should be carried out outside the summer period, when the operation of the cooling system is not necessary. It is estimated that the monitoring of the equipment is carried out by 2-3 persons, each with the help of a car, or a van. Repairs and maintenance are spare parts replacements, preservation and corrosion protection works (e.g. painting), which can be carried out periodically with 5-10 people and with the help of a van, a basket lifting machine or a car crane.

The EIA includes the assessment of environmental impacts resulting from above-described construction activities being necessary for the construction of the alternative warm-water channel and peak cooling system, which are based on the volume, duration and machinery requirements of the construction works.

2.2.2.2. Replacement of diesel generators, installation of replacement diesel generator

Regardless of the SSLE, the MVM Paksi Atomerőmű Zrt. continuously monitors the condition and reliability of all safety-relevant equipment, such as emergency diesel generators and associated auxiliary systems, including the future availability of spare parts supply for the equipment and maintenance background. For critical equipment, the MVM Paksi Atomerőmű Zrt. has plans to carry out any necessary replacements.

The point 2.1. of the opinion of the environmental authority concluding the pre-consultation included the following task related to the lifetime and reliability of safety diesel generator: *"As regards non-radioactive air pollution, it is necessary to examine the reliability, service life and releases of air pollutant of (two-stroke) diesel engines type 15 D100 with a rated thermal input of 4,502 kW/pcs for safety diesel generators connected to air pollution point sources P3, P4, P5, P6, P7, P8 , one engine for each air pollution point; and (four-stroke) diesel engine type PILSTICK with a rated thermal input of 6,285 kW/pcs for safety diesel generators connected to air pollution point sources P9, P10, P11, P12, P13, P14 , in terms of service lifetime extension, taking into account the provisions of the Decree of the Ministry of Agriculture (FM) 53/2017. (X. 18.) on operating conditions and emission limit values for air pollutants from combustion plants with a total rated thermal input of 140 kW_{th} and more but less than 50 MW_{th}, as well as its requirements from 1 January 2030."*

As part of the SSLE preparation, a separate time-limited aging analyses (TLAA) shall evaluate the extendibility of the lifetime of emergency diesel generators for the extended service lifetime. The test shall proof that the fatigue spare parts of the diesel generators conform to their strength and that fatigue cracks due to operational loads cannot not occur. The TLAA is also responsible for defining any additional technical and administrative measures that may be necessary for safe operation. These analyses are still ongoing, but based on the results of previous similar analyses, it is expected that they will demonstrate that the service lifetime of emergency diesel generators can be extended to the end of the SSLE period.

In units 1-2, the Russian-made diesel generator type 15D100 connected to the point source number P3, P4, P5, P6, P7, P8 are currently in satisfactory condition, their auxiliary systems are operational, and the necessary maintenance work is ensured. The priority at the moment is to ensure the maintenance and manufacturing background of the existing machinery fleet. Should the supply of spare parts and maintenance become uncertain in the future, the MVM Paksi Atomerőmű Zrt. will replace the equipment on the basis of previously prepared plans.

In units 3-4, the Hungarian-made diesel generator type 18PA4-V 185 VG GANZ-SEMT-PIESTICK connected to the point source number P9, P10, P11, P12, P13, P14 and their auxiliary equipment are currently in satisfactory condition, the necessary maintenance work and the supply of spare parts are ensured, and the NPP has two complete auxiliary equipment. Therefore, the possible replacement of this equipment is not planned.

The test for air pollutant release from diesel generators is set out in the working part on air quality protection in *Annex 1* and the results of the test are summarized in *Chapter 4.1*.

The MVM Paksi Atomerőmű Zrt. made a decision to install a new diesel generator, the so-called replacement emergency diesel generator for units 1-2. The replacement emergency diesel generator is a backup equipment which, in the event of a malfunction of an emergency diesel generator in any of the units 1-2' security systems (failure or failure in the planned mode (e.g. diesel reconstruction or diesel replacement), is suitable for the complete replacement of the inoperative equipment. The type of the new diesel generator has not yet been determined, and the MVM Paksi Atomerőmű Zrt. will select it through a tender.

The planned replacement emergency diesel generator has an effective electrical power of 2.3-2.5 MW and a nominal thermal input of 7,020-8,800 kW. The new diesel generator and its auxiliary equipment will be housed in a separate building with a floor area of approximately 250 m^2. The new diesel building will be built opposite the diesel engine room in units 1-2, next to the auxiliary building.

It is necessary to install underground fuel tank(s) next to the new diesel building, 2 pieces of 50 m^3 or 1 piece 100 $m^{3,}$ in order to maintain the automatic operation of the diesel engine for 120 hours.

The replacement emergency diesel generator shall in principle be in cold reserve operation if there is a failure in one of the diesel generators, or it is out of service, the replacement emergency diesel generator enters its place and is put into standby mode. As with other emergency diesel generators, it shall be subjected to regular running tests. The frequency of this will be determined by the manufacturer's specifications.

2.2.2.3. Diversification of fuel purchases

The supply and stocking of the fresh fuel, the so-called fuel assemblies, required for the operation of the Paks NPP has been and continues to be provided by TVEL, the Russian supplier dedicated to the NPP made by Russian design since the four units were put into operation.

The development and modernization of the fuel assemblies used in the power plant was a decisive element of the safety-enhancing measures and developments carried out during the nearly 45 years of operation of the NPP. Their primary goal is to use fuel as economically as possible, in full compliance with safety requirements, in such a way that the number of spent fuel assemblies generated during operation can also be reduced. In cooperation with the Russian fuel designer and manufacturer, the specialists of the Paks NPP have made several improvements. As a result, in 2015, it was moved from the previous 12-month cycle to the 15-month cycle, meaning that maintenance and fuel assembly replacement in the reactor was only required every 15 months instead of the former 12 months. As a result of a series of developments, it is now necessary to replace 96 fuel assemblies in 15 months instead of the former replacement of 114-120 fuel assemblies per year and per unit. Electricity production increased by a further 2-3% after the units increased their performance by 8%.

In the period following the commissioning of the units, only fuel assmblies that differed in the degree of uranium enrichment (1.6%, 2.4% and 3.6%) were used, for which different enrichments were necessary due to the reactor physical arrangement of the reactor loading.

Thanks to fuel developments initiated by specialists of the power plant, the Paks NPP was later granted permission to use additional fuel assembly types. These made it more economical and, due to the lower amount of spent fuel generated, even more environmentally friendly to operate, due to the modifications as determinative changes like higher enrichment (4.2% and 4.7%,) use of gadolinium as a burnout poison and, to a lesser extent, the modified uranium mass and smaller modification in rod size.

In all cases, the multi-stage developments were carried out in compliance with the relevant nuclear safety and environmental requirements and in addition to obtaining the necessary permits. For all modified fuel assembly types, it could be demonstrated that they do not result in significant changes in the release and environmental impacts of the NPP. On this basis, the most recent amendment of the environmental permit of the Paks NPP due to fuel development took place in 2021 with the issuing of a decision file number 121-14/2021 by the Baranya County Government Office. The Annex to the above decision sets out the typical parameters of the types of the fuel assemblies that can be used and stored in the NPP. These fuel assembly types and parameters were taken into account in the radiological protection analyses prepared for the basis of the Paks NPP SSLE EIA.

In line with its fuel consumption development strategy, the Paks NPP increase, before the start of the SSLE period, on one hand, the amount of fresh fuel stock that can be stored in the NPP so that the current 2-year quantity will increase to almost 3 years, and, on the other hand, the diversification of fuel purchase will be started. To perform the latter, the MVM Paksi Atomerőmű Zrt. entered into a contract with the Framatome-TVEL, a French- Finnish joint venture, as well as with the Westinghouse, an American company.

To increase the fresh fuel assembly stock, in 2027, the storage capacity of the power plant's fresh fuel storage room will be increased by expanding the storage grids. This has no impact, to be taken into account, from an environmental point of view, as it has no influence on the releases of the power plant, and the implementation of the technical modification is in line with the activities and maintenance that can be carried out under the current environmental permit.

In order to achieve the diversification of fuel purchases, the Framatome-TVEL joint venture, will not change the parameters of the supplied fuel assemblies for the additional two suppliers being present in addition to the TVEL, the current supplier. Regarding these fuel assemblies, it is a purchase of fresh fuel assemblies partly from another supplier (joint venture), but with the entirely same parameters as the currently authorized types, which only concerns the name of the supplier company for the purposes of environmental licensing.

In the case of fuel assemblies produced by Westinghouse, the technical parameters, which were defined jointly by the manufacturer and the experts of Paks NPP, change to a lesser extent.

The introduction of the use of Westinghouse fuel assemblies is planned in two steps, the first in unit 3. First in 2028 with so-called test fuel assemblies, then from 2029 with transhipment loads (96 fuel assemblies), the complete change of the zone is achieved gradually during the 15-month refuelling. Based on testing and operational experience and diversification options, it is planned to be used in other units from 2033 onwards, in line with the presumed operation permit for SSLE of unit 1.

In the long term, fuel consumption is planned by using Framatome-TVEL and Westinghouse fuel assemblies in parallel; using the same manufacturer's fuel in one unit. Once the stock of TVEL fuel assemblies has been used, they are replaced by Framatome-TVEL fuel assemblies.

The Westinghouse fuel assemblies will be very similar to the fuel assemblies currently authorized in terms of parameters, not irrespective of the reactor physical characteristics of the reactor type VVER-440. The UO_2 density and particle size are slightly different, the fuel pastilles containing burning-up poison are without central holes, and the structural materials are also different from the fuel currently used. Burning-up of the fuel assemblies will be slightly smaller due to a slightly larger uranium mass. However, the campaigns will continue up to 15 months.

Compared to the currently used TVEL fuel assemblies, despite the slightly different parameters, the Westinghouse fuel does not lead to a significant change in the environmental impact of the NPP operation and the interim storage provided by the PURAM. This statement is further

enhanced by the analyses carried out so far by experts of Paks NPP. Source strength analyses, isotope composition, volatile fission product, gamma and neutron spectrum analyses show that

- the remanent thermal output of the fuel assemblies during the decisive initial fallowing period is almost identical,
- the volatile fission products, once used in the reactor, show a good match to the similar results of the fuel assemblies currently used, with minor differences resulting from differences in uranium density and modelling assumptions, most of which represent only a few per cent or non-decisive differences,
- In line with the residual thermal power identity, the neutron and gamma spectrums are also very similar.

It can therefore, be preliminarily concluded that no substantial change is expected in terms of environmental releases and impacts compared to what has been determined and licensed on the basis of the fuel assemblies currently authorized and used.

As part of the design and approval of the fuel assemblies, of course, all the analyses necessary for the introduction of the Westinghouse fuel assemblies are carried out and repeated. The timing of their implementation is essentially determined, under the Act CXVI of 1996 on nuclear energy and its relevant decrees being currently in force, in particular, the OAH Decree 1/2022. (IV. 29.), by the preparation for nuclear safety licensing. In parallel to the nuclear safety analyses, the necessary analyses for environmental licensing will also be carried out, since the environmental permitting – according to the planned timetable for application – does not only cover the SSLE period, but also concerns the environmental permit currently in force.

On this basis, the finding based on preliminary assessment results at this stage, is justified, according to which, in addition to the Framatome-TVEL fuel assemblies, which are identical in terms of the technical parameters of the currently authorized fuel assemblies and introduced as part of the fuel diversification, the Westinghouse fuel assemblies do not result in any significant change in the environmental impact. For the preparation of the introduction of the fuel assemblies, in regarding the environmental impact assessment, there is no preparatory activity because the new fuel assemblies will arrive in the power plant as finished products.

From the point of view of the planned SSLE authorization in the Paks NPP, an independent task is, in synchronization with the application of the new fuel assemblies in the NPP, to obtain a permit on the interim storage of spent fuel assemblies at the Paks site, which task shall be carried out by the PURAM as SFISF licensee, both in terms of nuclear safety and environmental permitting. Section 38 of the Act CXVI of 1996 provides that *"Authorization for the use of nuclear energy shall only be granted if safe disposal of the radioactive waste and spent fuel generated is ensured, in accordance with the latest proven scientific findings, international expectations and experience"*.

Similarly, to the above, in terms of the power plant permitting, in the case of nuclear safety and environmental foundations and analyses falling within the scope of PURAM, no substantial changes are expected in the scope of the results and environmental impacts taken into account as a basis for the current permit of new fuel assemblies, with one exception. However, this one exception will not mean the parameters of the spent fuel assemblies, but the application of a new, even more modern interim storage technology. The preparation of the application of the new containerized interim storage technology started in 2026, on the one hand, with the decision on the application of the new technology at the level of the national economy, and on the other hand, with the establishment of the necessary trading conditions. The preparation for the environmental permit for interim storage of the technology described in the following chapter and the permit itself are carried out by PURAM, in terms of timing, synchronized with the environmental permitting of Paks NPP SSLE.

2.2.2.4. Modification of spent fuel management

Following the decision to prepare the SSLE of the Paks NPP, the MVM Paksi Atomerőmű Zrt. initiated a consultation with PURAM, the organization responsible for the interim storage of spent fuel, in order to determine the technology ensuring the interim storage of spent fuel assemblies

generated in the SSLE period. This was justified because the free storage capacity of the Spent Fuel Interim Storage Facility (SFISF), which ensures the interim storage of the amount of spent fuel assemblies generated during the 30-year service life and the current service life extension, will be used once the current 20-year service life extension has been completed.

A total of 28 storage chambers of the modular chamber dry storage facility (the English term for it is Modular Vault Dry Store /MVDS/), which was commissioned in 1997 and has since been expanded according to the rate of production of spent fuel, have been commissioned so far. PURAM has started preparations for the construction of the last 5 chamber module.

The construction of the SFISF with a total of 33 chambers was originally determined taking into account the power plant's 30-year operating life. The placement of spent fuel assemblies generated during the first 20-year service life extension in SFISF was ensured by increasing the capacity of the storage facility and increasing the number of fuel assemblies that can be placed in one chamber in two steps. The number of storage tubes for spent fuel assemblies in one chamber was increased from 450 to 527 first and then to 703 in the second phase. These are important to highlight, because, in this way, interim storage, including the amount of fuel assemblies generated during the service life extension, could be ensured within the framework of (environmental, site and nuclear safety), permits for the facility without the need to reserve additional areas. This also means that the application of the current MVDS technology linked to SSLE would require the use of additional areas in addition to the new licensing procedure.

Thus, the spare reserves of SFISF that could be taken into account for capacity expansion were essentially used. In addition, the revision of the storage technology to be used was justified by the fact that in the early 1990s, in addition to the MVDS technology, which was considered to be up-to-date at the time, newer, more modern, typically containerized technologies were also available with appropriate references. As part of this, in a first step, the MVM Paksi Atomerőmű Zrt. and PURAM evaluated the possibility of further technology expansion, or transition to container technology at the conceptual level. As a result of these investigations, it was decided in November 2025 that the interim storage of the surplus amount of spent containerized fuel assemblies generated during the SSLE period would not be ensured by the continuation of the MVDS technology, but by the transition to container technology within the current site of SFISF. During this period, mainly the implementation of surface container storage technologies in storage halls was investigated and the effects of technological change, including its environmental effects, were evaluated.

The change to container technology, which is planned for the SSLE period, will not lead to significant changes in the environmental impact of the technology, and the changes can also be considered positive in this respect. In the case of the currently used MVDS technology, containers are also used for the transfer from the NPP's spent containerized fuel pools to the SFISF. After filling the transport container C30 placed in the so-called shaft No. 1 of the NPP units from a spent fuel pool, and then, after the preparation for transport at the dedicated area in the reactor hall, the spent fuel assemblies are transported under water in the container to the storage facility. According to the transport capacity of the container C30, 30 fuel assemblies can be stored in the container, which are dried one by one in the drying pipe before being placed in the storage pipes in the SFISF.

The transition to dry container technology means that the preparation for transport in the reactor hall of the power plant and the preparation for dry storage in the SFISF are merged in one phase. In other words, the preparation for transport in the NPP is also the preparation for storage, which somewhat reduces the releases associated with the two operations and their effects. This reduction can also be considered to be favourable where the releases referred to are not environmentally determinant, due to the very low dose contributions. In fact, therefore, it is not even a problem that the release from dose constraint of 10 μSv/year applied to SFISF will be transferred to the 90 μSv/year dose constraint frame of 90 μSv/year applied to the NPP in the case of the new technology.

The different technological steps compared to the container C30, the dose contribution of drying and e.g. sealing by welding of the examined technology do not result in any significant change in the screened and monitored releases of the NPP based on the analyses carried out so far.

During the examination of the possibilities of transition to container technology, one of the possible suppliers came up with the possibility of using a new interim storage technology, which is even more favourable relating to the characteristics of the Paks site than the container technologies examined so far. Regarding the preparation of spent fuel assemblies for storage, the basis of the technology is the same as container technologies examined, with the difference that the interim storage does not take place on the surface, in a hall, but in a ventilated concrete structure built below the surface. The technology developed more than 10 years ago with appropriate reference facilities is the system called HI-STORM UMAX of the Holtec International company.

The spent fuel assemblies are placed in Multi-Purpose Canister (MPC) separating them from the environment. It is a thick-walled, weld-sealed stainless-steel tank that contains the fuel assembly in a fuel container (basket). References to several purposes should be understood that, where appropriate, this packaging unit may also be used for the final disposal of spent fuel. This can be very beneficial, because in this case the final disposal will not require repackaging, the individual handling of the fuel assemblies. In the case of fuel VVER-440 Paks, a total of 85 fuel assemblies can be placed in one MPC, taking into account the limits of subcriticality and temperatures. This amount of fuel assemblies is the same as the container capacity of the container technologies examined so far.

The UMAX system[6] is designed for long-term interim storage (in the United States, typically 100+ years are authorized by the nuclear safety authority of the United States, NRC). With the use of standard MPC, different types of spent fuel can be stored. The subsurface placement reduces the visual impact of the facility, increases safety, reduces exposure to external hazards and results in even lower dose contributions compared to surface storage solutions.

In addition to the interim storage of surplus spent fuel assemblies generated during the SSLE period within the current area of the SFISF, it is also a favourable feature that the use of this technology can ensure the interim storage of spent fuel of Paks II NPP in the area. Due to the size difference between the fuel assemblies of VVER-440 and VVER-1200, the placement of longer fuel assemblies in the current SFISF cannot be solved However, with the use of MPCs designed for the fuel assemblies VVER-1200 and the corresponding underground storage structure, the fuel of the Paks II NPP can also be placed there. In other words, this technology could be an alternative to the container storage technology currently considered in the case of the Paks II NPP.

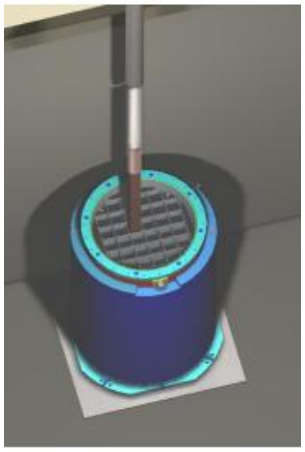
In the underground concrete system of UMAX, the passive cooling of MPCs is ensured by the natural air flow, essentially in line with the principle applied in MVDS technology. The system is a vertical ventilated module (VVM), each consisting of a hollow closed volume, Cavity Enclosure Container (CEC) and its associated closing lid. These ensure the physical protection, passive cooling and radiation shielding of the sealed fuel tank.

A so-called HI-TRAC preparation/refuel transport container is used to place spent fuel stored in the spent fuel pool in MPC and then prepare them for storage. The HI-TRAC container is a structure that provides the radiation and structural protection necessary for serviceability, including transportability, and is used for the MPC transfer in the area of the NPP and the SFISF between the preparation of the spent fuel pool in the reactor hall and the interim dry storage facility.

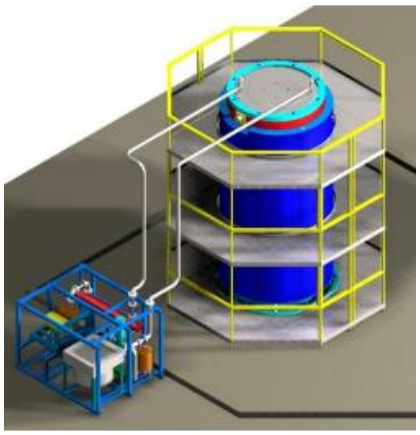
The filling and servicing of the installed MPC will be carried out in essentially the same way as the technology used for the container C30, with regard to the filling of the container in shaft No. 1 of the NPP unit. Next, in the service area of the container C30 in the reactor hall, the MPC placed into the HI-TRAC is sealed by welding, the water in the MPC is drained, the fuel assemblies are dried and filled with inert gas, and finally the openings necessary for the latter operations are sealed by welding, and then the compactness is checked *(Figure 2.2.2.4-1.)*.

The MPC prepared for storage is transferred to the SFISF area is placed in the storage structure and lowered to the HI-TRAC container by means of a dedicated Vertical Cask Transporter (VCT).

[6] https://holtecinternational.com/products-and-services/nuclear-fuel-and-waste-management/dry-cask-and-storage-transport/hi-storm/hi-storm-umax/



Filling the MPC with spent fuel assemblies



Sealing of the MPC by welding, water drainage, fuel assemblies drying and filling with inert gas

Source: Webpage of the International Atomic Energy Agency (www-pub.iaea.org/iaeameetings/cn226p/Session5/ID147Springman.pdf)

Figure 2.2.2.4-1. Filling the MPC with spent fuel and servicing them in the reactor hall of the NPP units

In the interim storage area, the HI-TRACK is placed above the designated storage shaft and, with adequate radiation protection, the MPC is lowered from the HI-TRACK into the storage shaft. The closing lid of the storage system and the components of the ventilation system are then placed on it.

An important part of the storage system is that recovery can be ensured, if necessary, i.e. the spent fuel assemblies in the MPC can, in a theoretical case, be returned to the spent fuel pool by re-wetting the fuel assemblies in the MPC, filling the MPC with water. However, such an operation is not necessary under normal operating conditions.

As an evaluation of the environmental impact of the transition to the UMAX technology, the operations associated with serving the container in power plant systems, as well as the relating releases have been reviewed. The EIA of interim storage and servicing in the area of SFISF is presented in the EIAR made by the PURAM regarding the capacity extension of the SFISF. However, on the basis of the technology and the operations described, it can be stated that the environmental impacts of SFISF will be determined by the new MVDS facility even if the new technology is applied. The contribution of the new technology will not be decisive due, in part, to the closed system and the underground location. In essence, the same conclusion is reached regarding the environmental impact of the preparation for interim storage in the Paks NPP. The number of fuel assemblies to be transported per year does not change. However, regarding the releases, it is somewhat more advantageous that instead of transporting the annual quantity by 30, which means 3-4 containers per year, after the introduction of the new technology, 1 container per NPP unit per year, it means - since there are four units - a total of 4 containers shall be served.

On the basis of the analyses carried out for the treatment operations, it can be concluded that the analyses carried out in the frame of the Paks NPP SSLE environmental impact assessment concerning the exposure of the population and their findings are also valid for the application of the UMAX technology. The substantive justification of all this will be ensured, similarly to the considerations made in relation to fuel diversification, by the preparation of the analyses necessary to provide the basis for the nuclear safety licensing.

2.2.2.5. Other planned measures and interventions

The technical conditions of the SSLE are based on continuous technical inspections, planned ageing management activities, refurbishments, equipment and tool changes and maintenance in the NPP. Continuous maintenance is planned on the basis of the following plans, programs and other records:

- The medium-term major overhaul plan, which identifies all tasks that may influence the major overhaul plans to be developed in lead time, resource expenditure, or special organization.
- Maintenance programs designed for each equipment group, individual equipment, which define the maintenance tasks to be performed during the given period and their schedule.
- Monitoring programs designed for individual systems, equipment groups and individual equipment, the successful implementation of which involves the technical and structural preparation of the NPP's systems and system components.
- Record of in-service failures and related technical decisions, where necessary interventions and implementation conditions are defined.

The multi-level planning practice (long, medium, campaign plans) developed for the implementation of maintenance, testing and surveillance programs aims to provide the system with the necessary flexibility to organize its implementation. Another important aspect is that the built-in checkpoints for the preparation of campaign plans ensure the gradual clarification of resource needs and the verification of their availability.

On the basis of lifetime management programs, taking into account design and production specifications, operational, testing and maintenance experience, long-term and campaign period maintenance plans are compiled and updated, as well as campaign period volume is compiled to determine maintenance conditions.

The activities summarized as follows should be carried out independently of the plans for SSLE, but should also serve as a basis for their implementation. In the coming years, it will become unavoidable for several equipment to be replaced, given the lack of replacement spare parts, or the wear and tear, or obsolescence of the equipment. The responsible departments of the NPP planned the following equipment- and device- replacements, refurbishments and reconstructions for the following years:

- Reconstruction and reinforcement of principal operational buildings, auxiliary buildings, diesel engine rooms, sanitary and laboratory buildings, warm-water channel and other structures. The need for work is usually estimated upon the condition inspection report.
- Reconstructions of equipment, pumps, heat exchangers, fittings, compressors, filter replacement, spent fuel pool and refuelling pool in the reactors.
- Replacement of elements of communication technology systems, which is necessary due to the obsolescence of hardware and software devices of communication systems and the technological changes.
- Refurbishment of radiation control systems, partial or, for some system components, complete, e.g. replacement of data loggers, replacement of computers due to obsolescence.
- Replacement and refurbishment of instrumentation and control equipment; taking into account further SSLE, a complete refurbishment is expected to be necessary. The replacement of the spare parts of the turbine power control system is currently difficult, its maintenance needs are increasing, and a complete reconstruction becomes necessary. The control equipment and devices installed in the water intake plants are mostly of original installation, their maintenance needs are increasing, and a complete reconstruction is expected to be necessary.
- The refurbishment of the elements of the radioactive waste classification system means a complete refurbishment of the gamma spectrometry measuring system, because the units of the measuring system become irreparably obsolete every 15 years, or so.
- As a periodic refurbishment of radioactive waste treatment technologies, installation of a radioactive waste compactor press, removal of ^{60}Co, replacement of complex dismantling equipment, refurbishment of FHF technology equipment, periodic refurbishment of cementing technology.
- Periodic refurbishment of the elements of the radioactive waste compactor press and cementing equipment are necessary due to wear and tear. This includes ^{60}Co removal, complex dismantling equipment modification, operational security transformations.

- The refurbishment of the fire alarm system elements includes the replacement of the fire alarm and fire extinguishing control system elements; the reconstruction is necessary due to technical amortization and spare parts supply problems. (Note that some of the electronic, digital devices are expected to have to be replaced again during the service life extended.)
- Other reconstruction-related activities also include:
  - an evaluation of the replacement of pumps in the high-pressure emergency core cooling system, the possibility of failures due to the design of the pumps and frequent maintenance justify the replacement of the pump (or, alternatively, the retrofitting of the pumps, the refurbishment of the hydraulic part),
  - reconstruction of the hermetic carbon steel lining, correction of defects discovered during the work related to the integrity of hermetic spaces (hermetic space monitoring and repair program), carrying out the reconstruction of the lining (reconstruction works can be carried out on the long major overhaul),
  - replacement of ventilators due to the expiry of their service life,
  - replacement of liquid nitrogen storage tanks, replacement of liquid nitrogen evaporator,
  - replacement of high-pressure nitrogen gasifier due to loss of spare parts supply,
  - construction I. (units 1-2) development of a long-term strategy for emergency diesel generators with regard to the possibility of full or partial replacement,
  - the replacement of transformer stations in the external operating distribution network is current, the supply of spare parts is limited, and their maintenance needs are increasing,
  - replacement of steam generator sludge system armatures due to an increase in the frequency of failures.
- Refurbishment of electrical, building engineering, sanitary unit, sewage pumps, replacement of instruments and aggregators.
- Replacement of chemical analysers and ion chromatographs covering the chemical sampling system.
- Refurbishment, reconstruction and replacement of lifting machines, replacement of luminaires and electric motors.

The preparation of the SSLE therefore partly involves carrying out the necessary interventions related to the authorized 50-year operation. However, the works falling within the scope of regular maintenance shall be carried out continuously during the extended service lifetime. This is supplemented by targeted activity, only necessary for the SSLE. *Table 2.2.2.5-1.* and *2.2.2.5-2.* summarize the interventions and reconstructions affecting the individual architectural facilities and technological systems of the NPP. *Table 2.2.2.5-1.* shows the planned tasks prior the SSLE period *Table 2.2.2.5-2.* shows the tasks for the SSLE period.

Table 2.2.2.5-1. Planned reconstructions of architecture structures, technology system and their expected environmental impacts during the SSLE preparation period

System / equipment / structure	Reconstruction / intervention	Place of work	Environmental consequence	Waste management					
				Normal wastes			Radioactive wastes		
				Not hazardous [t]	Hzardous [t]	Total [t]	Low and intermediate level [t]	High level [t]	Total [t]
Interventions on architecture structures and its environmental consequences									
Main operational buildings	Small structure reinforcement	In the building	Waste generation	–	–	–	863.50	–	863.50
Sanitary and laboratory building	Roof insulation reconstruction	In the courtyard	Waste generation Non-significant external releases from machinery work	–	28.80	28.80	–	–	–
Diesel engine rooms	Reconstruction of buildings	In the courtyard	Waste generation Non-significant external releases from machinery work	–	90.00	90.00	–	–	–
Warm-water channel	Earthwork repair	In the courtyard	Non-significant external releases from machinery work	–	–	–	–	–	–
Interventions on technology equipment and its environmental consequences									
Main equipment									
Equipment within the reactor	Change of intermediate rods for control and safety protection cassettes, change of reactor cask screws	In the building	Waste generation	–	–	–	–	9.28	9.28
Reactor coolant pumps	Replacement of disc spring assemblies	In the building	Waste generation	–	0.10	0.10	15.00	–	15.00
Control rod drive systems	Change of drives	In the building	Waste generation	26.75	–	26.75	92.88	–	92.88
Mechanical systems									
Armatures	Replacement, repair and refurbishment of armatures	In the building	Waste generation	35.09	0.20	35.28	12.35	1.00	13.35
Pipelines	Change of pipelines, route modification, pipe tunnel reconstruction	In the building	Waste generation	60.00	–	60.00	–	–	–
Diesel generators	Complete or partial change of emergency diesel generators I. construction	In the building	Waste generation	291.00	9.00	300.00	–	–	–
Hoisting machines	Change of cranes, hand chain blocks, refurbishment of track, engine, control device and drive of the trolley	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	54.70	3.30	58.00	24.48	–	24.48
Heat exchangers	Change of heat exchanger, modification of pipeline connection, other additions	In the building	Waste generation	0.25	–	0.25	0.60	–	0.60

System / equipment / structure	Reconstruction / intervention	Place of work	Environmental consequence	Waste management					
				Normal wastes			Radioactive wastes		
				Not hazardous [t]	Hzardous [t]	Total [t]	Low and intermediate level [t]	High level [t]	Total [t]
Air technology, gas technology equipment	Change of summarize gas blowers, evaporators, gasifiers, compressors, fittings	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	46.08	–	46.08	1.20	–	1.20
Valves	Replacement, change and modification of safety and control valves	In the building	Waste generation	106.05	–	106.05	25.08	–	25.08
Pumps	Replacement and refurbishment of pumps	In the building	Waste generation	830.10	–	830.10	76.26	–	76.26
Filters	Refurbishment of filters, change of filter housings	In the building	Waste generation	53.90	0.85	54.75	–	–	–
Vessels	Vessel replacement, replacement of rubber coating	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	3.00	12.00	15.00	–	–	–
Ventilators	Replacement of ventilation systems equipment (engine, coating)	In the building	Waste generation	4.365	0.135	4.50	–	–	–
Other mechanical equipment	Replacement, refurbishment of other mechanical engineering equipment	In the building	Waste generation	396.50	14.20	410.66	159.1	50.00	209.10
Electrical systems									
Accumulator sets	Replacement of fixed accumulator sets	In the building	Waste generation	5.50	307.5	313.00	–	–	–
Distributors	Replacement and refurbishment of distributors with different voltage level	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	67.34	32.96	100.30	3.00	–	3.00
Generators and auxiliary equipment	Replacement of turbogenerators, replacement and refurbishment of their auxiliary equipment	In the building	Waste generation	1,730.00	103.00	1,833.00	–	–	–
Cables, cable transits	Refurbishment and replacement of cables, hermetic cable transits	In the building	Waste generation	515.73	20.75	536.48	502.10	–	502.10
Distribution equipment	Replacement and refurbishment of distribution equipment, control boards, distribution boards	In the building	Waste generation	5.50	20.10	25.60	–	–	–
Circuit breakers	Major maintenance of machine voltage circuit breakers	In the building	Waste generation	1.00	–	1.00	–	–	–

System / equipment / structure	Reconstruction / intervention	Place of work	Environmental consequence	Waste management					
				Normal wastes			Radioactive wastes		
				Not hazardous [t]	Hzardous [t]	Total [t]	Low and intermediate level [t]	High level [t]	Total [t]
Uninterruptible power supplies	Replacement and refurbishment of uninterruptible power supplies	In the building	Waste generation	4.40	6.80	11.20	–	–	–
Filler equipment	Replacement and refurbishment of filler equipment	In the building	Waste generation	9.80	2.70	12.50	–	–	–
Transformers	Refurbishment and replacement of unit transformer equipment	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	41.00	10.00	51.00	–	–	–
Electrical engines	Replacement and refurbishment of electrical engines	In the building	Waste generation	173.00	1.40	174.40	0.10	–	0.10
Instrumentation and control systems									
Control equipment (elements of control, regulator, measure and signal systems)	Replacement and refurbishment of the equipment, refurbishment of the networks affected	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	105.46	76.08	181.54	0.25	–	0.25
Communications systems									
Telecommunication systems, alarm, information and other data transmission systems	Replacement of elements of communication systems, review of networks, replacement of terminals, if necessary	In the building	Waste generation	1.88	1.80	3.68	–	–	–
Fire protection systems									
Fire extinguishing systems	Replacement of fire water network armatures, replacement of ball valves	In the building	Waste generation	22.00	–	22.00	–	–	–
Fire alarm systems	Refurbishment of fire alarm and fire extinguishing control systems	In the building	Waste generation	3.62	0.78	4.40	0.10	–	0.10
Chemical systems									
Chemical sampling system	Reconstruction of equipment, replacement of fittings and armatures, replacement of analysers	In the building	Waste generation	0.82	1.28	2.10	0.50	–	0.50
Radioactive waste management									
Qualification system, solid and liquid radioactive waste management equipment	Refurbishment and replacement of equipment	In the building	Waste generation	20.00	1.15	21.15	12.00	–	12.00
			Total:	*4,614.84*	*741.68*	*5,359.67*	*1,788.50*	*60.28*	*1,848.78*

Table 2.2.2.5-1. Planned reconstructions of architecture structures, technology system and their expected environmental impacts during the SSLE period

System / equipment / structure	Reconstruction / intervention	Place of work	Environmental impact	Waste management					
				Normal wastes			Radioactive wastes		
				Not hazardous [t]	Hazardous [t]	Total [t]	Low and intermediate level [t]	High level [t]	Total [t]
Interventions on architecture structures and its environmental consequences									
Main operational buildings	Replacement of fire-resistant asbestos coating	In the building	Waste generation	–	3,300.00	3,300.00	–	–	–
Auxiliary buildings	Refurbishment of buildings	In the building	Waste generation	–	–	–	0.55	–	–
Water intake structure building	Asbestos removal	In the building	Waste generation	–	150.00	150.00	–	–	–
Interventions on technology equipment and its environmental consequences									
Main equipment									
Equipment within the reactor	Replacement of intermediate rods for control and safety protection elements	In the building	Waste generation	–	–	–	–	1.68	1.68
Control rod drive systems	Change of drives	In the building	Waste generation	38.09	–	38.09	132.25	–	132.25
Mechanical systems									
Armatures	Replacement, repair and refurbishment of armatures	In the building	Waste generation	40.50	–	40.50	73.60	2.00	75.60
Diesel generators	Replacement of diesel generators	In the building	Waste generation	7.50	1.50	9.00	–	–	–
Hoisting machines	Renovation of power cranes in technical buildings and workroom, replacement of engine room gate	In the building	Waste generation	13.80	1.80	15.60	5.60	–	5.60
Air technology, gas technology equipment	Replacement of gas blowers and high-pressure compressors	In the building	Waste generation	11.60	–	11.60	–	–	–
Filters	Replacement of the carbon filling of absorber filters	In the building	Waste generation	20.00	4.00	24.00	56.00	–	56.00
Turbine condensers	Reconstruction of units 1-4 turbine condenser	In the building	Waste generation	1,600.00	–	1,600.00	–	–	–
Other mechanical equipment	Replacement, refurbishment of other mechanical engineering equipment			35.93	0.617	36.55	3.60	–	3.60
Electrical systems									
Accumulator sets	Replacement of fixed accumulator sets	In the building	Waste generation	5.00	288.00	293.00	–	–	–
Distributors	Replacement and refurbishment of distributors with different voltage level	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	405.10	109.60	514.70	1.00	–	1.00

System / equipment / structure	Reconstruction / intervention	Place of work	Environmental impact	Waste management					
				Normal wastes			Radioactive wastes		
				Not hazardous [t]	Hazardous [t]	Total [t]	Low and intermediate level [t]	High level [t]	Total [t]
Generators and auxiliary equipment	Replacement of turbo generator protections, repair of generator systems	In the building	Waste generation	84.10	21.50	105.60	–	–	–
Distribution equipment	Replacement and refurbishment of distribution equipment, control boards, distribution boards	In the building	Waste generation	15.50	32.50	48.00	–	–	–
Circuit breakers	Major maintenance of machine voltage circuit breakers	In the building	Waste generation	19.00	1.00	20.0	–	–	–
Uninterruptible power supplies	Replacement and refurbishment of uninterruptible power supplies	In the building	Waste generation	33.40	30.30	63.70	–	–	–
Filler equipment	Replacement and refurbishment of filler equipment	In the building	Waste generation	9.80	2.70	12.50	–	–	–
Transformers	Refurbishment and replacement of transformers and auxiliary equipment	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	30.10	8.90	39.00	–	–	–
Control systems									
Control equipment (elements of control, regulator, measure and signal systems)	Replacement and refurbishment of the equipment, refurbishment of the networks affected	In the building / in the courtyard	Waste generation Non-significant external releases from machinery work	90.61	151.50	242.10	0.32	–	–
Communications systems									
Telecommunication systems, alarm, information and other data transmission systems	Replacement of elements of communication systems, review of networks, replacement of terminals, if necessary	In the building	Waste generation	1.98	1.90	3.88	1.00	–	1.00
Fire protection systems									
Fire alarm systems	Refurbishment of control elements of fire alarm systems	In the building	Waste generation	0.36	1.44	1.80	–	–	–
Chemical systems									
Chemical sampling system	Equipment reconstruction, replacement of hardware and software	In the building	Waste generation	0.02	0.28	0.30	–	–	–
Radioactive waste management									
Qualification system, solid and liquid radioactive waste management equipment	Refurbishment and replacement of equipment	In the building	Waste generation	16.64	1.01	17.65	6.50	–	6.50
			Total:	*2,479.03*	*4,108.55*	*6,587.57*	*280.42*	*3.68*	*283.23*

The first column of the tables contains the names of the individual structures and technological equipment groups affected by the reconstruction. In the second column is the planned work, in the third column is its location. The expected environmental impact factors and impacts are identified in the fourth column; i.e. basically only waste generation is to be expected from the given activity (reconstruction works carried out inside the building) or other environmental impacts can also be assumed (e.g. air pollutants and noise emissions from mechanised work in the yard). The following columns describe the type and quantity of waste generated per type.

On the basis of the data in the tables, it can be established that the environmental impact of the maintenance and renovation of the NPP's buildings and building structures, is not expected to significantly exceed the conventional environmental impact associated with normal, current operation, but in the case of reconstructions that typically involve demolition, a higher amount of waste is expected to be generated. The interventions described in the tables, which are necessary for the preservation of buildings and structures, may cause a temporary local effect, limited to the duration of their construction, which is expected to remain within the site.

In the case of interventions concerning technological systems and equipment included in the tables, it is specified whether the work is carried out inside a building, or outside a building in a courtyard. The tables show that the environmental impact factor resulting from the reconstruction works carried out inside the building is – conventional and radioactive – waste generation. The works carried out in the courtyard represent environmental factors and impact processes corresponding to the conventional construction impacts, i.e. primarily air pollutant and noise emissions, and may result in the generation of conventional (non-hazardous and hazardous) waste. These works can mostly be carried out as part of the maintenance tasks of the type-year, which are still carried out continuously, thus their volume and expected effects can be considered to be largely the same as the works carried out during the previous service lifetime. Therefore, apart from an individual case (e.g. replacement of a fire-safety asbestos coating), no significant difference or increase in environmental consequences is expected.

When refurbishing some equipment, conventional environmental impacts such as construction activities should also be taken into account. However, the 50 years of operation and the additional interventions planned for extension are not expected to increase this type of load. It can also be shown that the volume of deliveries is not increasing (limited to a shorter delivery period at most). However, these short periods are typically related to the performance of major overhaul, and can also be observed in current operations.

An important aspect of the grouping of planned activities is the type of waste generated during the interventions. During the necessary maintenance and refurbishment, radioactive waste is generated in the case of equipment in contact with radioactive materials, while conventional industrial waste is generated in the case of non-contact or decontamination equipment and spare parts. As most of the equipment renovations and replacements are carried out as part of the usual activities, significantly more waste is not expected to be generated than the currently usual types of waste, with the exception of some planned reconstructions involving a significant amount of waste (e.g. structural reinforcement of principal operational buildings, replacement of asbestos coating). The volume of waste is largely in line with current operational practice.

In the framework of the preparation of the SSLE, on the basis of the above review of the measures and interventions included in the other group of activities and transformations planned for SSLE, it can be concluded that, in the context of the environmental impact assessment of the SSLE, waste generation as an environmental impact factor likely to have a significant impact had to be examined in detail. Other factors that can be linked to the planned reconstructions (e.g. air pollutant and noise emissions) have characteristics similar to those occurring in connection with the current operation. Therefore, they will not be independently examined in detail.

2.2.2.6. Assessment of preparatory activities for SSLE from the perspective of expected environmental impacts

Among the technical and technological modifications described in *Chapters 2.2.2.1. – 2.2.2.5*, planned to be carried out as part of the preparation of the Paks NPP SSLE, significant environmental impacts are expected from the construction and operation of an alternative warm-water channel and peak cooling system, from the operation of replacement emergency diesel generator in units 1-2, and from the implementation of reconstruction works classified in other categories concerning the NPP's structures, mechanical, electrical and control systems, examined and assessed in the environmental impact assessment.

The construction of the alternative warm-water channel and peak cooling system requires mechanised earthworks, construction and installation activities that result in significant air pollutant and noise emissions, waste generation, and can also have an impact on the state of environmental elements, biological population and living communities. The environmental impact of the construction works was assessed in the context of the environmental impact assessment. In connection with the operation of the peak cooling system, the cooling cells were also tested as sources of noise, in addition to which the effects of the cooling cells on climatic conditions were also evaluated. With the construction of the alternative warm-water channel, a new Danube inlet point will be established, which has been analysed as part of the Danube heat load test, considering that, thanks to the operation of the peak cooling system at the new inlet point, the temperature of the warmed cooling water returned to the Danube can be reduced during critical periods.

The replacement emergency diesel generator planned for units 1-2 qualifies as a stationary air pollutant point source, and the effects of its air pollutant emissions have been assessed as part of the environmental impact assessment.

Waste generation is the determining environmental factor in the case of reconstructions classified in other categories affecting the NPP's structures, mechanical, electrical and control systems. The characteristics expected quantities and treatment options of the conventional (non-hazardous and hazardous) and radioactive waste generated were evaluated as part of the EIA.

The detailed assessment of the expected environmental impacts resulting from the implementation of the SSLE preparatory activities, as described above, is set out in the individual discipline-specific annexes of the EIAR, the results of which are summarized in the sub-chapters of *Chapter 4* and *5*.

2.2.3. Activities required to establish a nuclear safety licensing of the SSLE

2.2.3.1. Nuclear safety authority procedures

To the SSLE of the NPP, in addition to the environmental license, it is also necessary to obtain nuclear safety permits. The licensing procedure is two-stage; the adjudicating authority is Hungarian Atomic Energy Authority (HAEA).

As a first step of the procedure, 4 years before the expiry of the operation permit, the implementation program of Paks NPP units 1-4 SSLE is submitted to the HAEA at the same time as the official notification of the renewal intention, which sets out all the necessary steps to ensure that the establishment and continuous maintenance of the safety of the NPP is feasible and verifiable, and that the requirements of the licensing can be met.

In the second stage of the procedure, one year before the expiry of the operation permit of the given unit, applications for operation permit for the SSLE period shall be submitted to the HAEA separately for each unit.

The documentation on which the permit is based shall contain the following main elements:

- reviewing the design basis of the units,
- reviewing the comprehensive ageing management system of the Paks NPP, reviewing/developing the ageing management programs of specific system elements/groups, thus ensuring that the condition and safety function of the system

elements falling within the scope of ageing management is continuously monitored during the extended service lifetime.
- assessment of the technical condition of the NPP and certification of the suitability of the system components for the extended service lifetime,
- establishing and implementing a system for monitoring the effectiveness of maintenance and reporting the experiences to the authority on a quarterly basis,
- environmental performance assessment of electrical and control technical components,
- reviewing and carrying out ageing analyses that limit the lifespan and are valid for a limited period of time, and taking the necessary measures based on the results of the analyses.

The listed reviews and analyses are carried out in parallel with the environmental licensing and during the SSLE preparation period continuously.

2.2.3.2. Investigations on which the nuclear safety licensing is based

The HAEA renews the operation permit on the basis of the consideration of safety, so the procedure covers all systems classified in nuclear safety classes, which have to perform the intended safety function during the entire service lifetime. System components with non-safety functions shall also be included in the scope of consideration, the failure of which may hinder/influence/endanger systems and system components with safety functions in the performance of their tasks.

In order to establish the SSLE, it must be demonstrated that the condition of the system components allows for further operation. Condition inspections of the NPP's systems and construction structures are carried out from the commissioning. The relevant inspection programs, pressure tests, structural tests and periodic inspections include both destructive and non-destructive material tests. In recent years, the technical quality of the tests has continuously improved, both in terms of tools and procedures. Material tests shall be conducted and certified in accordance with the methods recommended by the European Network for Inspection Qualification.

In addition to the routine and condition inspection, which are in line with the NPP’s practice, special tests will be carried out to evaluate the condition of all important key system components and construction structures, to the extent and by the method agreed with the authority. These tests were carried out mainly in structural locations, which are not part of the periodic inspections, but based on the analysis of ageing processes limiting the lifetime, a one-off test appears necessary. On the basis of the tests to be carried out, it must be demonstrated that the construction structures and equipment of the NPP are in a condition suitable for further operation, are free from defects and that the values of the material characteristics are above the values required.

The authorized service life of the NPP and the validity of the operation permit in time are primarily limited by the functional life defined in technical and safety terms, which is proven by Time-Limited Ageing Analyses (TLAA).

Based on the analyses carried out by the designer, the Final Safety Analysis Report of the Paks NPP Units 1-4, which reflects today's expectations, and the international practice, the scope of the TLAAs to be performed was determined after reviewing similar analyses of more than 30 NPPs, with special regard to the characteristics and problems of Paks. During the preparation of the SSLE, 32 TLAA are planned to be carry out in advance:

TLAA1 Low-cycle fatigue analysis of ABOS 1-2 (safety classification) mechanical systems and components.
TLAA2 Environmental qualification of electrical and instrumentation and control systems and components.
TLAA3 Pressurized Thermal Shock (PTS) analyses of reactor pressure vessels.
TLAA4 Determination of pressure – temperature (*p*-*T*) curves for the primary circuit.
TLAA5 Crack growth analyses.
TLAA6 Thermal stratification analyses of ABOS 1-2 piping systems.

TLAA7 Extension of high-energy pipe break analyses.
TLAA8 High-cycle fatigue analysis of flow-induced vibration of reactor internals.
TLAA9 High-cycle fatigue analysis of flow-induced vibration of steam generator tubes.
TLAA10 Analysis of material property changes in reactor internal structures.
TLAA11 Fatigue analyses of containment penetrations.
TLAA12 Fatigue analyses of containment structure components (welds).
TLAA13 Analysis of thermal ageing embrittlement of ABOS 1-2 mechanical systems and components.
TLAA14 Fatigue analyses of cranes performing safety functions.
TLAA15 Fatigue analysis of spent fuel pool liners.
TLAA16 Analysis of material property changes in steam generator tubes.
TLAA17 Analysis of material property changes in heavy concrete structures.
TLAA18 Analysis of integrated leak-rate tests at elevated pressure.
TLAA19 Analysis of corrosion wall-thickness allowances.
TLAA20 Fatigue analysis of the main coolant pump flywheel.
TLAA21 Analysis of building settlement and its consequences.
TLAA22 Assessment of B10 depletion of spent fuel pool racks.
TLAA23 Analysis of embedded flaws in the heat-affected zone of reactor vessel cladding.
TLAA24 Analysis of material property changes in the ceramic thermal insulation of the upper block.
TLAA25 Fatigue assessment of spent fuel storage racks.
TLAA26 Fatigue assessment of the fuel handling machine.
TLAA27 Fatigue assessment of containment airlocks.
TLAA28 Fatigue assessment of diesel generators.
TLAA29 High-cycle thermal fatigue analysis of cracks identified in the guide vane and discharge cover of the main coolant pump.
TLAA30 Lifetime-limiting analysis of the steel thermal insulation support structure of the reactor shaft wall.
TLAA31 Assessment of material degradation processes affecting the reactor pressure vessel support ledge and supporting steel components.
TLAA32 Analysis of liner defects and leakage in the spent fuel pool and transfer pool.

There are two options for the outcome of the analyses:

- In most cases, the results of extended or repeated analyses demonstrate that the specified limits (e.g. number of load cycles) are not reached by the tested structure, so the statement of operability also applies to the service lifetime subsequently extended.
- If the results of the extended or repeated analyses/tests demonstrate that the serviceability is shorter than the extended service life, a targeted ageing management program or other measures (e.g. replacement, refurbishment of equipment, retesting at a later time) should be applied or planned to address the specific problem.

2.2.3.3. Review of ageing management programs

The Paks NPP introduced ageing management programs that detect the ageing processes of buildings, building structures and system components in a timely manner, effectively prevent the effects of ageing, and reduce or improve the deterioration effects that may have occurred. During the preparation of the SSLE, these programs will be reviewed and, if necessary, new programs will be developed.

A differentiated, incremental approach generally applied in the nuclear industry is applied according to the safety significance of the given structure or system element, as well as the nature and significance of the given ageing process limiting the lifespan of the power plant. Accordingly, system elements can be divided into two categories:

- System components of particular importance for nuclear safety, such as the main equipment of the reactor pressure vessel or the reactor cooling circuit, i.e. devices classified as safety class 1 and some devices classified as safety class 2. Individual (specific) aging treatment programs have been prepared for this system component scope.
- Ageing management groups have been defined, i.e. sets of system components in which the system components or construction structures are of similar construction and material, operate in the same medium and thus age in a similar way, so it is sufficient to manage them with a common program. Approximately 90 aging management groups have been defined for mechanical system components, nearly 30 for construction structures and 16 for electrical and control engineering groups. Thus, in the Paks NPP, about 100,000 system elements belonging to the range of aging treatment can be treated with nearly 150 aging treatment programs.

Proof of the suitability of these programs is an important chapter in the permit documentation required for SSLE. In the course of verifying the suitability of ageing management programs, a complete review of previous ageing management practices is also carried out, with the necessary modification of existing programs and, in some cases, the preparation of new ones. In the course of the review, recommendations on the structure and content of the official HAEA guidelines No. 4.12. for ageing management programs were applied, which are in line with the USA practice (Generic Aging Lessons Learned (GALL) Report, NUREG-1801) and the expectations of the International Atomic Energy Agency (IAEA Safety Standards Series No. NS-G-2.12, Ageing Management for NPPs).

The lifetime of the Paks NPP as a whole facility with four units is determined by those structures and system components that are not replaceable, non-refurbishable (long-life) or the associated costs and downtime are so high that it is technically and economically unreasonable to replace them. Examples include the reactor pressure vessel, steam generators and containment. One of the most important questions of the SSLE is whether the expected lifetime of non-replaceable, large technological equipment can serve an additional 20 years of uptime.

On the basis of the currently available material testing, analysis and maintenance results, none of the most important equipment from the point of view of nuclear safety– reactor pressure vessels, steam generators, hydro-accumulators, volume compensation tanks, main gate valves, main circulation lines – should be considered to be impossible or costly during the extended service lifetime of 50+20 years. All known technical information indicates that it is highly probable that the plant will be able to operate for 70 years.

In order to meet nuclear safety requirements, due to the conservatism of design and, as part of the conservatism, the fact that the loads are less than assumed and, in part, the introduction of 15-month operating cycles, long-life structures and equipment have a significant lifespan reserve. This makes it possible to extend the service lifetime of key components, while at the same time extending the service lifetime of the power plant, without reducing the minimum safety reserves, which should be taken into account in the design as a limit or by the application of safety factors, by more than permissible.

The most important condition of the SSLE is the technical condition (availability) of the systems, system components, constructions and structures in accordance with the requirements during the period of subsequent service lifetime. To this end, the specialists of the NPP, taking into account the extension to 50+20 years of operation, have developed a program of reconstructions based on the current and expected state information of mechanical, electrical and control systems, system components, buildings and structures.

The implementation of the reconstruction program should primarily take place during the planned main repairs and during the maintenance of the security systems in operation. Several major refurbishment tasks are expected which involve significant disruption of the technological systems, for which the 25-55-day time interval and technological conditions of the main repairs will not be sufficient, so a longer, several-month shutdown per unit will be necessary during the preparation of the SSLE.

2.3. Design operating conditions and other operating conditions that may cause environmental impact, possibility of emergency events

2.3.1. Operating conditions, incidents with radiological effect

Definition of the operating condition of a NPP and the requirements for the nuclear safety analyses can be found in the Nuclear Safety Code (NSC) annexed to requirements the OAH Decree 1/2022. (IV. 29.) on nuclear safety requirements for nuclear facilities and related activities of the authorities.

Section 3.2.2 of Volume 3 of the NSC, which defines the design requirements for operating NPPs, address the categorization of NPP operating conditions and potential incidents. According to the provisions therein, conditions deviating from normal operation must be classified into operating conditions belonging to the design basis (DBC) and operating conditions constituting an extension of the design basis (DEC). Normal operation, as well as events leading to conditions considered part of the design basis of the NPP being already operated, must be assigned to operating conditions according to their frequency, as specified in *Table 2.3.1-1*.

Table 2.3.1-1. Incidents leading to conditions considered as part of the NPP design basis and their frequencies

Operating condition*	Description	Event frequency (f [1/year])
DBC1	Normal operation	–
DBC2	Anticipated Operational Occurrences	$f \geq 10^{-2}$
DBC4	Design Basis Accidents	$10^{-2} > f \geq 10^{-5}$

* The legislation applies the DBC3 category (low-frequency design basis incidents, where $10^{-2} \geq f \geq 10^{-4}$) only to newly constructed NPP units. Accordingly, the extreme value of the frequency of DBC4 events for these units an order magnitude lower, i.e., $f \geq 10^{-6}$.

In the case of incidents with a lower expected frequency of occurrence than design-basis incidents, activity release leading to public doses exceeding the limits for design-basis incidents may occur. As an extension of the design basis, the legislation distinguishes between the categories of complex accidents (DEC1) and severe accident (DEC2). In these cases, to prevent and mitigate consequences, failure and accident management measures must be implemented. These are contained in the Comprehensive Emergency Management and Response Plan (ÁVIT), the State-Oriented Management Instructions (ÁOKU) and the Severe Accident Management Guide (SBKU). These measures are intended to mitigate both on-site and environmental impacts.

Based on the legislation containing domestic nuclear safety requirements, the Paks NPP's operating conditions can therefore be classified into the following categories:

- normal operating condition (DBC1),
- anticipated operational occurrences (DBC2),
- design bases accidents (DBC4),
- complex accidents (DEC1),
- severe accidents (DEC2).

NSC also sets out different acceptance criteria for conditions other than normal operating conditions – in accordance with their varying frequencies. Of these, the following are also relevant for the compilation of this EIAR.

For processes arising from an initial event resulting in operating conditions DBC2-DBC4, it must be proven that the dose per person for the relevant population group does not exceed:

a) the dose constraint value for the public in the case of a process arising from an initial event resulting in the DBC2 operating condition, and
b) for processes resulting from an initial event resulting in a DBC4 operating condition, the value of 5 mSv/event.

Taking into account all planned operating conditions and assumed initial events, except for sabotage, the frequency of zone damage leading to severe-accident release shall not exceed 10^{-4}/year.

The cumulative frequency of severe-accident event chains with high, or early release shall not exceed 10^{-5}/year for all initial operating conditions and impacts, except in the case of sabotage and earthquakes, but shall be approximated to 10^{-6}/year using all reasonable adaptations and interventions.

Compliance with the relevant acceptance criteria is proven by safety analyses for all initial events, part of the design basis and its extension. Probabilistic safety analysis is used to determine the total risk posed by the NPP, to verify compliance with the relevant acceptance criteria, to evaluate the balance and consistency of the designs and to assess the adequacy of the extension of the design basis. The probabilistic safety analysis shall be used to demonstrate that sufficient reserves are in place to avoid cliff edge effect. Fulfilment of the requirements shall be presented in the FSAR containing the content specified in the NSC and shall be accepted by the HAEA, the authority responsible for the supervision of nuclear safety.

2.3.2. Operating conditions and configurations relevant to environmental impacts

The environmental impact assessment of the extension of the Paks NPP's 50-year service life by another 20 years required an analysis of several operating conditions and configurations, taking into account the preparation of the SSLE and its implementation.

According to the amendment to the legislation (Section 10/A of Decree 15/2001. (VI. 6.) KöM), which entered into force in 2024, and is also relevant for the preparatory phase, the 30°C limit value for the temperature of warmed cooling water returned to the Danube “may be exceeded for reasons of security of supply with the consent of the minister responsible for energy policy”. The impact assessment for this operating condition is prepared on the basis of the recommendation of the Advisory Board for Sustainable Nuclear Energy established by the minister responsible for energy policy, as follows:

- the water temperature of the Danube, measured at its reference section of 500 m measured from the water inlet, does not exceed 32°C,
- a case-by-case derogation may be applied for a maximum of 15 days within a calendar year,
- the backload of the Paks NPP does not exceed half of the nominal capacity of the facility.

The above-mentioned legislative amendment is particularly important because it avoids the forced loading of the NPP at a time when the security of electricity supply may be endangered due to the technological conditions of the NPP and the time-consuming nature of the loading. This is the case, for example, when it is no longer possible to supply photovoltaic electricity of an otherwise significant capacity that is lost in the evening due to darkening. In the EIA analyses, this operational status has been identified as “32/15 rule” for easier identification.

The scope of the investigations and analyses necessary for the assessment of the environmental impact of the SSLE was further extended by the ongoing construction of the Paks II NPP, which made it necessary to take into account, not only the four-units configuration of the Paks NPP, but also the two new units in Paks (Paks II NPP).

As a basis for the environmental permit of the new units, the environmental impacts of the construction of the NPP next to the operating units in Paks were assessed in detail. In the case of the analyses carried out during that period, it was assumed that the new units would still be put into operation in the current operating time extension cycle of the Paks NPP. Consequently, the plant with six units was only assessed over a period of a few years, not assuming the need for the implementation of the Paks NPP SSLE.

The establishment of the Paks II NPP started in February 2026 with the first concrete casting of unit 5 moved from the previous, practically preparatory phase to the implementation phase. According to the International Atomic Energy Agency's terminology, the new unit is already qualified as facility being under construction. Subsequently, in addition to the scheduled

construction of the foundation slab of unit 5, the work pit of unit 6 was also raised to the design level.

In addition to the Paks NPP site, the two new units of the Paks II NPP (units 5-6), which is to be built in an area neighbouring to the area of the units 1-4 being in operation, will be built in the investment of the Paks II. Atomerőmű Zrt. as a company independent from MVM Paksi Atomerőmű Zrt.

In part by the two independent companies and in part by other circumstances determining the progress of the establishment, which could, where appropriate, accelerate or slow down the completion of the construction of new units, the assessment of the environmental impacts of the Paks NPP SSLE required a number of power plant configurations to be taken into account. The variants assessed are as follows:

The power plant configurations evaluated as part of the EIA and assessed by the field-specific annexes forming the annexes to the EIAR thus included, on the one hand, the operation of the SSLE without Paks II NPP and also the joint operation, i.e. the separate operation of the Paks NPP and the joint operation of the Paks NPP and the Paks II NPP. The 'state of play' evaluations assessed as part of the environmental impact assessment covered, mutatis mutandis, the operation of the Paks NPP.

For the purpose of assessing the combined impacts of the two NPPs, the scope of the assessment of each field involved in the assessment was further extended by taking into account, for the six-unit plant, the peak cooling system ensuring compliance with the criterion of the Danube's thermal load limit, where this was justified for the purposes of carrying out the tests. Consequently, for certain areas involved in the assessment, the joint operation of the Paks NPP and the Paks II NPP was distinguished without taking into account or taking into account the peak cooling system to be installed in connection with the Paks NPP. It should be emphasized that this distinction was made for analytical purposes only, because, according to the assessment results, it will be possible to avoid the forced loading of the Paks NPP units during periods of exceptionally high Danube water temperatures in the summer, only by operating the Paks NPP's peak cooling system during the period of the six-unit operation. On this basis, the assessments covered the following operating conditions and configurations in areas involved in the assessment:

- independent operation of the Paks NPP, current status,
- Paks NPP SSLE as independent operation,
- Paks NPP "32/15" operation,
- Joint operation of Paks NPP and Paks II NPP (where it was necessary separately assessed with or without the consideration of the Paks NPP peak cooling system).

2.3.3. Emergency events with conventionsl environmental impact

2.3.3.1. Failures of the main nuclear technology

The analyses contained in the Paks NPP Final Safety Analysis Report (FSAR) analyse the events taking into account the aspects of nuclear safety and radiation safety in order to verify the conformity with the relevant legislation, mainly the requirements and criteria set out in Volume 3 of the Nuclear Safety Code annexed to the OAH Decree 1/2022. (IV. 29.). As a consequence, analyses are presented up to and including the first stable condition, as appropriate, or up to a condition in which processes involving damage to the active zone or exceeding the release criteria can be excluded. On the other hand, the scope of the analyses is limited to scenarios whose conduct and conservatism are sufficient to justify nuclear safety. Taking into account the above, on the basis of a review of the analyses contained in the FSAR, the following non-radiation protection events affecting the environment related to the failures of the main nuclear technology were examined in the context of the EIA. The evaluation of the environmental impact of the failures with radiological consequences is provided in *Chapter 5.3.*

Noise emissions and air pollution were assessed in the scope of non-radiation protection events as failures of the main nuclear technology.

Events with stronger and more persistent noise emissions may include those involving the opening of the safety valve that reduces to the atmosphere or generates steam. The other events have practically no noise impact beyond the site boundary. This may include items from “Initial Event Group 2, C” and “Initial Event Group 8, ATWS”, as numbered and named in the FSAR. In ATWS (Anticipated Transient Without Scram) events, the essential assumption is that there will be no automatic reactor shutdown due to a fault.

In addition to the long-term opening of a steam generator safety valve, as an events of the initial event group 2, the event described in the chapter “Closing of a steam side isolation valve, determination of the maximum turbine pressure” of the FSAR is relevant. Here, the noise effect is continuous and does not disappear during the period of analysis (1000 s). During events involving the closing of 5 or 6 steam generator isolation valves, several safety valves can operate simultaneously, however, the noise effect is not continuous, but the steam generator safety valve opening and closing cycles alternate.

The events of the initial event group 8 were analysed using realistic (best-estimate) methods. Ultimately, from this group, also the events belonging to the heat removal decrease, are expected to have significant noise effect due to the sound of the safety valve reducing the significant noise effect to the atmosphere and generating steam.

In the case of air pollutant emissions (exhaust effects) from diesel generators, the continuous operating time of 12 diesel generators for a continuous operating period of 120 hours is assumed as a conservative casing event in the case of a total voltage loss.

2.3.3.2. Emergency events other than main nuclear technology

Before determining the possible events to be considered, it was taken into account that the NPP was designed to achieve a high level of safety, both for the main technology and for the service sub-technologies. Thus, events that could be considered for the analysis of calamity events are in fact events with a negligible probability compared to conventional industrial events. The true safety of the facility from this point of view is adequately presented in the safety report serving as a basis for the disaster management licensing, the operational water quality emergency response plan plan as well as in the chapter of FSAR dealing with fire protection systems. On this basis, it was not justified to carry out new analyses by identifying new postulated emergency events, but the existing analyses could be used to demonstrate the environmental compliance of the facility, given that the analyses contained in the above documents were accepted and approved by the competent authorities.

2.3.3.2.1. Hazardous substances, soil contamination

The following facilities were selected for further analysis in the safety report serving a basis for the NPP’s disaster management licensing:

- Further analysis of diesel engine room I and II in relation to the presence of diesel as an ecotoxic substance – after HAZOP (Hazards and Operability Analysis) is not further discussed in the report.
- Salt storage colour (ammonium hydroxide storage) – after HAZOP is not further discussed in the report.
- Pipeline system transporting hydrazine to the primary circuit, since the toxicity value of this facility was the highest, the substance has a possible carcinogenic effect and the minimum distance from the operational area boundary is 40 m. During the event under investigation, a pipe fracture occurs on the non-excludable section of the NA50 courtyard pipeline. In the scenario, the total quantity of 200 g/l of hydrazine hydrate consigned simultaneously to the pipeline after dilution, 1.8 m^3, escapes into the environment. This is the theoretical maximum amount that can be escaped. The instantaneous escape of hydrazine hydrate accumulates in a puddle over an area of 300 m^2 under the pipeline.

Based on the characteristics of previous emergency events affecting soil quality related to the operation of the NPP (*Table 4.1.4-1. Annex 4.*), the release of contaminants used in the power

plant to the soil and into the soil may also occur as a result of damage to subsurface tanks and fittings.

2.3.3.2.2. Water pollution

Water pollution may occur in the following emergency event:

- In the event of transport accidents, chemical, or oil spills, pollution can enter the rainwater sewerage located in the courtyard. The rainwater collected from the paved surfaces in the power plant area is fed into the built-up rainwater collection system, from where it is introduced into the warm-water channel through the pump house of the southern artificial canal:
  - The maximum amount of oil entering the warm-water channel (lubricating oil, hydraulic oil, waste oil) shall be 0.5 m^3, taking into account transport modes and pollution response actions.
  - The maximum amount of chemical input into the warm-water channel shall be 0.5 m^3, taking into account transport modes and pollution response actions.
    Types of chemicals: nitric acid (HNO_3) 58-68%,
    hydrazine hydrate ($N_2H_4 \cdot H_2O$) 55%,
    ammonium hydroxide (NH_4OH) 25%,
    sodium permanganate ($NaMnO_4$),
    hydrogen peroxide (H_2O_2).
- Communal sewage treatment plant failure:
  As a result of the failure of the domestic sewage treatment plant, a maximum of 300 m^3 untreated domestic sewage will be discharged into the warm-water channel for 1 day.
- Turbine engine room oil system failure:
  In the event of a major flooding failure and an oil run-off of more than 12 m^3, turbine oil may enter the closed section warm-water channel. The maximum amount of oil released into the warm-water channel during a possible failure can be estimated at 15 m^3.

2.3.3.2.3. Fire cases

Fire cases can occur as follows:

- Combustion of waste stored in hazardous and industrial waste containers.
- Generator transformer fire (with multiple levels of protection).
- Main oil tank or gravity oil tank fire (with multiple levels of protection).

2.3.3.3. Emergency events involved in the environmental impact assessment

Among the possible calamity events described above, those listed in *Table 2.3.3.3-1.* were selected in the environmental impact assessment for detailed analysis in the fields indicated in the table. The principle of selecting the emergency events to be involved in the EIA was that the given event should, in terms of the environmental impact caused, cover the effects of another possible emergency event.

Table 2.3.3.3-1. Proposed involvement in the environmental impact assessment

Emergency event	Affected environmental element, system						
	Air	Surface water	Soil, groundwater	Groundwater base	Wildlife	Noise	Waste
2.6 Simultaneous loss of external electric feed-in and internal AC feed-in – all 4 units*	X					X	
Pollution of hazardous substances on and into the soil (in the most typical sources due to damage to subsurface tanks and fittings), oil pollution			X		X		X
Leakage of materials containing radioactive isotopes to soil due to technological failure			X				
Water pollution through the warm-water channel, failure of the communal sewage treatment plant (300 m^3/d of untreated sewage entering the Danube through the warm-water channel).		X		X (indirect)			

* Considering which safety devices will start and which ones will stop operating normally during the calamity event.

2.4. Environmental facilities and measures, release and environmental monitoring systems

2.4.1. Monitoring of environmental release and state of the environment

The Paks NPP operates under the provisions set out in the consolidated environmental license, file number 391-18/2017 issued by the Baranya County Government Office on 9 June 2017 and its amendments. The NPP has been in operation for several decades and environmental factors, impacts and impact processes related to its operation are known. The activities carried out to monitor environmental releases and the state of the environment ensure the traceability of the environmental impacts of the power plant and the verifiability of compliance with environmental standards by providing detailed and up-to-date information on releases and the state of the environment. The activity of the NPP is also governed by regulations and policies regarding environmental protection, some of which are approved by the environmental authority in accordance with its competence and legal requirements.

The environmental measures, procedures and inspections introduced and applied are basically appropriate also for the period of the SSLE and are suitable for monitoring the environmental emissions of the NPP and the state of the surroundings of the power plant. In the event of future legislative changes, major modifications to NPP's systems or possible changes in environmental conditions, the power plant's environmental measures, policies and practices shall be reviewed as necessary and, where appropriate, amended or supplemented. As a guarantee, the NPP operates an Environmental Management System certified according to the MSZ EN ISO 14001:2015 standard.

Existing environmental monitoring activities will of course be continued by the MVM Paksi Atomerőmű Zrt. extending to the period of the SSLE. Due to the transformations that are planned

to be carried out in preparation for the SSLE, as described in *Chapter 2.2.2.*, it is also necessary to complement certain activities related to the monitoring of environmental releases.

The main environmental monitoring activities and measures required by the NPP's environmental license and carried out in connection with the operation of the NPP are the following:

Radiation protection

- Examination of the exposure of the biological population:
  Repeated every five years, samples from the selected sampling sites are taken twice in the test year (spring, autumn) and the samples are subjected to ^{3}H and gamma spectrometry measurements. Gamma spectrometry results are provided for all isotopes that are regularly released from the power plant (e.g. ^{54}Mn, ^{58}Co, ^{60}Co, ^{134}Cs, ^{137}Cs).
- Monitoring of accumulation of isotopes release from the NPP in environmental media:
  Gamma spectrometry measurements of soil and Danube sediment are carried out at the same sampling points as the exposure of biological population, also with a frequency of 5 years. Gamma spectrometry results are provided for all isotopes that are regularly released from the power plant (e.g. ^{54}Mn, ^{58}Co, ^{60}Co, ^{134}Cs, ^{137}Cs).
- Control of radioactive releases:
  A release control system is operated in order to determine the radioactive releases. The control of the power plant's releases is carried out in accordance with the provisions of the current Emission Control Regulation (KiESZ).
- Control of the environmental impact of radioactive releases:
  An environment control system is operated in order to determine the environmental impacts of radioactive releases. The control of the power plant's surroundings shall be carried out in accordance with the provisions of the Environmental Monitoring Regulation (KöESZ).

Water protection

The impact of NPP's warmed cooling water and wastewater on the Danube's water quality and biological population is monitored by a proper monitoring system that meets the requirements of the Water Framework Directive. Controls shall be carried out every three years, on a seasonal basis. In order to characterize the ecological status of the Danube, the following groups of organisms and their chemical characteristics are examined:

- Groups of organisms:
  - phytoplankton: composition, density,
  - phytobenthos: composition, density,
  - macrozoobenton: composition, density,
  - fish: composition, population, age structure,
- Chemical characteristics (water):
  - oxygen flow indicators (dissolved oxygen, BOD, COD),
  - major cations and anions,
  - electrical conductivity,
  - suspended solids and organic matter content;
  - organic micro-contaminations,
  - plant nutrients,
  - a-chlorophyll,
- Chemical characteristics (sediment):
  - organic micropollutants.

The test shall be carried out every three years, seasonally, on the following sections:

- 1,534.0 rkm Paks ferry left, right bank, middle,
- 1,525.8 rkm mouth section of the warm-water channel right bank, middle,
- 1,526.2 rkm large spur left, right bank, middle,
- 1,525.0 rkm Uszód left, right bank, middle,

– 1,516.0 rkm Gerjen-Foktő left, right bank, middle.

The water use groups of the power plant are as follows:

– water used for cooling, which is fully returned to the receiving Danube,
– technological supply of makeup water,
– social water supply,
– fire water supply.

The cooling water of the power plant and the raw water used in the technological makeup water preparation are supplied from the Danube, the drinking water demand is provided from the Csámpa wells (layer water), and the water supply of the fire water system is provided from bank-filtered wells.

The sampling site V4 established in the energy-breaking structure of the warm-water channel (*Figure 2.4.1-1.)* serves to ensure both authority and self-control sampling. The sampling site represents the quality of the combination (origin) of all used water discharged into the Danube and the treated wastewater.

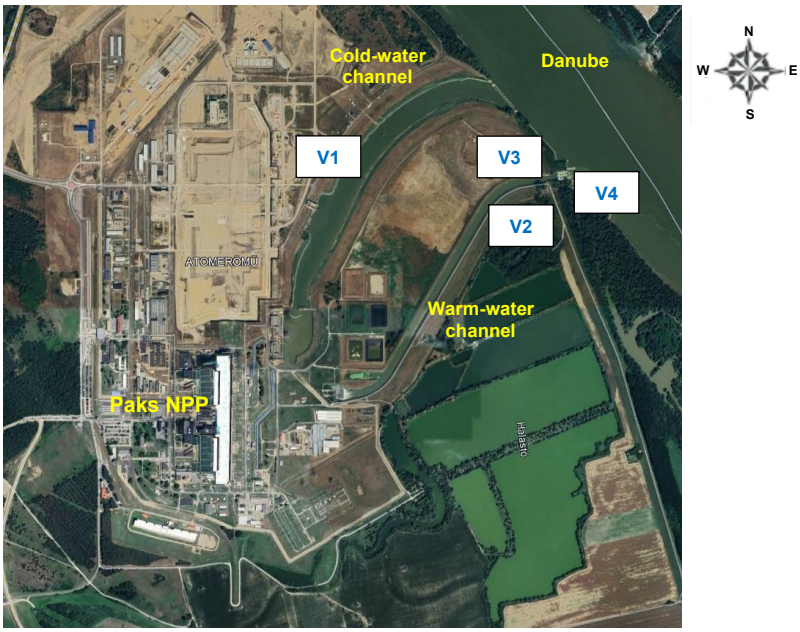


Figure 2.4.1-1. Location of the sampling stations V1, V2, V3 and V4

The sampling site V1 built next to the cold-water channel continuously monitors the radiometric characteristics of the Danube, the sampling site V2 at the end of the warm-water channel, the spout condenser, the safety and technological cooling water, the water taken over from the pools located in tailing area and the rainwater taken over from the south swale. The combined characteristics of the treated faecal wastewater discharged from the discharge line and the above-balance water are measured by the equipment of the sampling site V3. Continuous sampling for laboratory testing is also carried out at each station (*Figure 2.4.1-1.)*. In the framework of the current monitoring program, all parameters set according to the limit value in the water rights permit are monitored.

Protection of the Danube's biological population against thermal loading

The temperature of the current Danube water taken out for cooling and the warmed cooling water to be discharged (at the point of discharge) is continuously measured. If the Danube water temperature is expected to reach or exceed 25°C in the Paks water level gauge section according to the daily forecast of the National Hydrological Forecasting Service, compliance with the 30°C limit is checked by manual measurement in the Danube's 1,525.5 rkm section.

According to NPP's current environmental license, file number 391-18/2017, compliance with the 30°C heat limit shall be monitored in accordance with the methodology set out in the assessment

made by the Department of Sanitary and Environmental Engineering of Budapest University of Technology and Economics (BME) on *"Development of the operational system related to the thermal load of the Paks NPP and examination of the improvement of mixing"*.

In its opinion file number 383-100/2024 concluding the preliminary consultation, the environmental authority requested a review of the methodology contained in the above assessment made in September 2010. The required review was carried out by the BME Department of Water Engineering and Water Management in 2025. The objective of the measurement methodology is to continuously ensure legal compliance and to designate the possible backload of the power plant taking into account environmental variables. On the basis of the review, it was found that, taking into account the criteria set out in the legislation, the current measurement and evaluation methodology continues to be appropriate, given that it was specifically designed taking these aspects into account.

According to the NPP's policy on Danube water high temperature, when the Danube's water temperature reaches or exceeds 25°C according to the daily report of the National Hydrological Forecasting Service, the Government Office shall be notified in writing within 4 hours of its detection. If the Danube water temperature reaches or exceeds 25°C at 11:00 a.m., the continuous compliance with the 30°C limit shall be checked by manual measurement from a measuring vessel in the reference section. The Government Office shall be given the opportunity to participate in extraordinary measurements.

The advantage of the measurement at 11:00 a.m. is that it represents well the daily temperature evolution of the Danube, while providing the opportunity for timely operational interventions. Although the maximum daily temperature is not yet recorded at this hour, according to historical statistical data (Paks water level gauge, 2000-2025), the water temperature is now close to the daily average (which is an important indicator from an operational point of view), and the rate of warming is also at its steepest stage (*Figure 2.4.1-2.).*

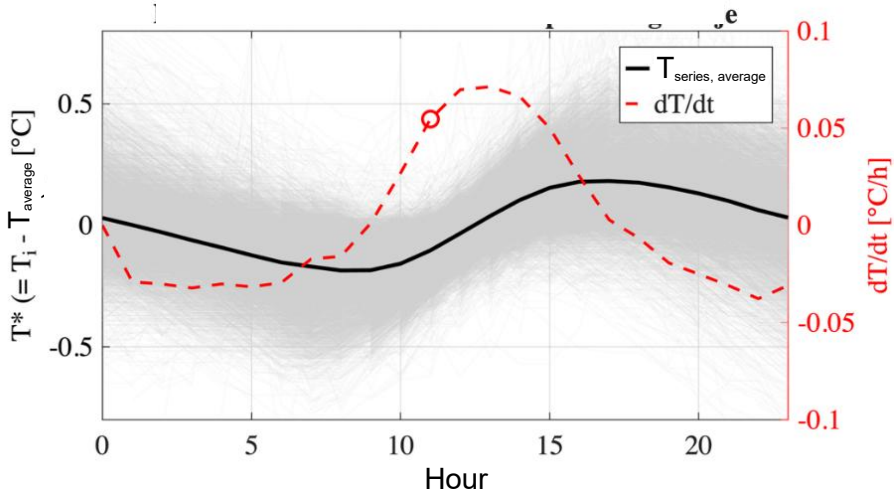


Figure 2.4.1-1. Daily running curve of normalized water temperatures

The required measuring time has a double advantage. On the one hand, it provides an accurate picture of the daily average temperature conditions, and on the other hand, it allows the necessary operational decisions (e.g. backloading the power plant) to be made in a timely manner before the maximum water temperature is reached. This not only makes the control of the heat load of the river more efficient, but also reduces environmental risks by giving time to prepare the necessary operational measures.

The impact of power plant's warmed cooling water and wastewater on the Danube's water quality and biological population is monitored by a proper system every three years that meets the requirements of the Water Framework Directive. Tests shall be carried out during the growing season as provided for in the environmental license.

Protection of bank-filtered water bases being operated and of long-term importance

The power plant operates a monitoring system established in order to protect the bank-filtered water bases operating on the Danube section affected by the discharge of used water and of long-term importance (monitoring the impacts on groundwater) in accordance with the provisions of the current water permit.

The power plant's impact on groundwater and soil is monitored by an extensive groundwater monitoring well system. In the monitoring system, 42 groundwater monitoring wells are monitored for different parameters depending on the technology monitored. In order to monitor the movement of groundwater and possible contamination, the water level of 118 wells is recorded, including 18 wells with automatic water level recording equipment.

In order to control potential sources of contamination, monitoring of the environment of the following facilities shall be carried out:

- waste collection point at site,
- industrial tailings area,
- underground oil tanks,
- domestic sewerage system.

Monitoring the status of the Danube bed and the bank wall

In order to monitor changes in the status of the Danube bed and the bank wall, the tests previously carried out are repeated every 10 years.

Checking the status of ABOS class 4 systems

The results of the monitoring program established in relation to the ageing of ABOS class 4 systems, which pose a risk to the environment in the event of their failure, and the associated maintenance (refurbishment) schedule, as well as the program for the assessment of the environment impacts, shall be submitted to the environmental authority with a frequency of five years.

Waste management

The MVM Paksi Atomerőmű Zrt. meets the power plant’s waste management objectives – reducing the quantity and hazardousness of the waste generated, maximizing the rate of recovery of the waste generated and further developing the system of separate collection of waste – in a scheduled manner, taking into account environmental and economic aspects.

Air cleanliness protection, operation of air pollutant point sources

The operating time of the safety diesel generators is 50 hours per year. Only diesel fuel with a low sulphur content (below 0.05 m/m%) is used as fuel. Compliance with the release limit values for air pollutants set out in the environmental permit for air pollutant point sources shall be monitored every five years by means of a standard emission measurement carried out by an accredited measurement body.

Protection against noise

The MVM Paksi Atomerőmű Zrt. ensures compliance with the noise limit values in accordance with the current legal requirements.

Planned additions to the monitoring of environmental releases

As part of the preparation of the SSLE, it will be necessary to supplement the release and environmental monitoring activities due to the entry into operation of the alternative warm-water channel section and the replacement safety diesel generator among the planned modifications described in *Chapter 2.2.2.*

With the planned construction of the warm-water channel section, a new water entry point from the power plant into the Danube will be built at a distance of about 350 m south of the existing one, with the construction of an energy-breaking structure similar to the existing one (*Chapter 2.2.2.1.*). Implementation of a new measurement and water sampling site therefore

planned at the alternative warm-water channel section where it enters the Danube, equivalent to the water quality measurements (sampling stations V2, V3 and v4) currently carried out before the existing warm-water channel is connected to the Danube. The range of water quality characteristics tested at the new measurement site and the method of measurement will be the same as at the existing sampling site V4.

Given that the replacement safety diesel generator to be installed qualifies as a stationary point source for air pollutants, similarly to existing safety diesel generator, compliance with the emission limit values for air pollutants set out in the environmental license is monitored every five years by means of a standard emission measurement carried out by an accredited measuring body.

2.4.2. Structure and operation of the radioactive release and environmental monitoring system

The general task of the release and environmental monitoring required by the Ministerial Decree 15/2001. (VI. 6.) KöM on radioactive releases into air and water and their monitoring during the use of nuclear energy is to provide sufficient and reliable direct measurement data at all operating conditions of the NPP to assess the expected environmental effects and, where appropriate, to take the necessary measures. In the case of the Paks NPP, the order of monitoring is laid down in the Emission Control Regulation and Environmental Monitoring Regulation approved by the Baranya County Government Office. Tests relating to the monitoring are conducted by the Emission Control Laboratory and the Environmental Control Laboratory of the NPP.

2.4.2.1. Operation and structure of the emission monitoring system

The control of liquid and gaseous releases of the NPP is characterized by two levels of monitoring. Continuous, typically integrated measurement data from in-site release monitoring telemetry systems are supplemented by laboratory testing of a large number of samples of releases from sampling monitoring.

Telemetry systems are used to monitor liquid and airborne radioactive releases and to quickly monitor changes in releases.

The scope of the sampling control of release, the sampling processing technique and the achievable characteristic detection limit for normal operation are summarized in *Table 2.4.2.1-1.*

A system of regulatory limits is used, which compares both liquid and aerial release activity to isotope-specific release limits derived from a dose constraint (90 μSv) specified for the NPP.

Table 2.4.2.1-1. Laboratory radiation monitoring of the release of radioactive materials by sampling

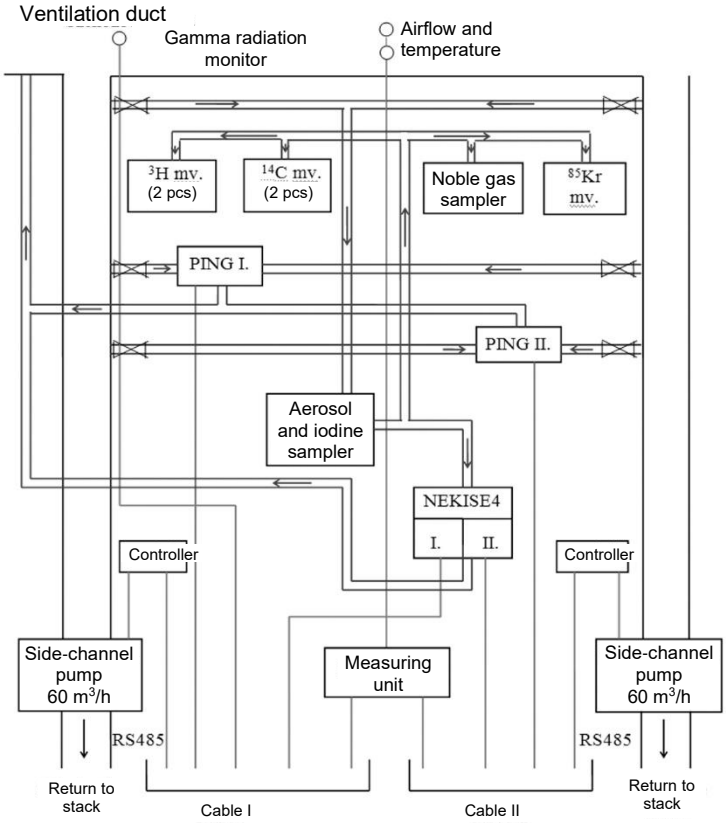
Monitoring direction		Measurement frequency	Number of samples per year	Sample processing	Sample size	Method of measurement	Measure-ment time [s]	Detection limit [Bq/dm^3]
Liquid release								
Total beta	from vessel	Daily (as required)	1,000	Evaporation (100 cm^3)	f = 50 mm bowl	Total beta counting	3,000	3
	V1, V2, V3	On weekdays*	1,100	Evaporation (300 cm^3)	f = 60 mm bowl		10,000	0.05
Isotopic composition	from vessel	Weekly	208	–	1 dm^3 Marinelli	Gamma-spectrometry	50,000	0.5
	V1, V2, V3	Monthly*	36	Evaporation (30x500 cm^3)	35x35x5 mm		50,000	0.001
Tritium	01/02TM50	Weekly and monthly	256	Distillation	20 cm^3 cuvette	Liquid scintillation counting	3x60	200
	XZ, RJ-RZ						3x600	9
	V1, V2, V3	Monthly*	36				18,000	2
Radiostrontium	from vessel	Quarterly	12	Chemical separation	20 cm^3 cuvette	Liquid scintillation	36,000	0.03
	V1, V2, V3	Quarterly*	12		f = 50 mm bowl	Beta counting	50,000	0.001
Radiocarbon	from vessel	Quarterly	12	Chemical separation	20 cm^3 cuvette	Liquid scintillation	3,600	0.1
	V1, V2, V3	Quarterly	12				3,600	0.1
Alpha emitters	from vessel	Quarterly	16	Chemical separation	f = 25 mm disc	Alpha-spectrometry	50,000	0.0001
Total alpha	from vessel	Daily (as required)	280	Evaporation	f = 50 mm bowl	Total alpha counting	3,600	0.25
	V1, V2, V3	Quarterly	12	Chemical sep. (150 cm3)	f = 25 mm disc	Alpha-spectrometry	60,000	0.01
X-ray emitters	from vessel	Quarterly	16	Evaporation (1000 cm^3)	5 cm^3 sample holder	X-ray spectrometry	50,000	0.4
Airborne release								
Aerosol, radioiodine		On weekdays	1,464	–	f = 50 mm bowl	Gamma-spectrometry	5,000	0.01
		Weekly	416				50,000	0.0004
Radiostrontium		Quarterly	12	Chemical separation	20 cm^3 cuvette	Liquid scintillation	36,000	1x10-5
Noble gas		On weekdays	520	–	7,32 dm^3 bottle	Gamma-spectrometry	5,000	5x103
Tritium	HTO, HT	Biweekly	240	Desorption	20 cm^3 cuvette	Liquid scintillation	3x600	0.05
Radiocarbon	C_nH_m	Biweekly	224	Chemical separation	20 cm^3 cuvette	Liquid scintillation	1,200	0.4
	CO2						3,600	0.25

*The tests are carried out by the Environmental Control Laboratory.

2.4.2.1.1. Monitoring of atmospheric release

During operation of the NPP units, radioactive materials may be released into the environment along the route and to the extent permitted by the authorities. Release monitoring is a documented demonstration of compliance with regulatory limits on release of radioactive isotopes under normal operating conditions. In the event of a failure or accident-based radioactive release, they provide guidance for estimating the expected environmental radiation conditions.

The conceptual scheme of the air protection monitoring system emitted through the ventilation chimney is shown in *Figure 2.4.2.1.1-1.*



Source: Sándor Deme and Csilla Pesznyák (edit.): Radiation protection in practice, Typotex Publishing, 2024.

Figure 2.4.2.1.1-1. Schematic drawings of the atmospheric release

Structure of the air sampling and flow measurement system

Isokinetic sampling system

In the isokinetic sample measurement system, two completely independent isokinetic measuring circuits operate parallel to each other in normal operation. Measuring circuits are capable of replacing each other by an external command. The function of the measuring circuits is to supply the chimney release monitoring measuring devices with an isokinetic and representative sample of the air flowing through the main ventilation duct, and to communicate the current, momentary sampling values to the central computer.

Air velocity / volume flow measurement system

The air velocity / volume flow measurement system consists of two air velocity / volume flow measuring circuits with velocity probes as common components. The measurement points of the main air flow velocity are determined according to the standards MSZ ISO 9096:1994 and VDI 2066 at 9 points. The function of the air velocity / volume flow meter circuit is: continuous and long-term measurement of the current velocity and volume flow of the main air flowing through the ventilation bridge from primer circuit rooms, and communication to the central computer of current, momentary values (2x9 air velocities per construction).

Telemetry systems

The PING system

There are two so-called PING systems per chimney pair, both PINGs consisting of independent parallel branches of completely identical structure, both of which are supplied by the isokinetic sampling system with air samples from the ventilation bridge. The PING system is used to measure the α- and β activity concentration of released air aerosols, the ^{131}I γ-activity concentration of elemental and organic phase radioiodine and the total β-activity concentration of radioactive noble gases. It consists of three separate instruments connected in series in terms of airflow: a radio aerosol meter, a radioiodine meter in elemental and organic form, and a radioactive noble gas meter. From the isokinetic air sampler, the air sample is first transferred to the aerosol, then to the iodine and finally to the noble gas meter. The pump in the noble gas metering unit returns the measured air to the chimney.

NEKISE system

The continuous-action gamma-spectrometry measuring system (NEKISE) with the same structure per pair of chimneys is suitable for isotope-selective quantitative measurement of noble gas emissions. The air sample from the ventilation bridge passes through the isokinetic sampling system passing the combined samplers (aerosol, elemental and organic iodine filters) and, after merging the three parallel branches, descends to the low-background measuring chamber at the bottom of the chimney, where two HPGe (high purity germanium) semiconductor detectors are located.

Measured noble gas isotopes: ^{85m}Kr, ^{88}Kr, ^{133}Xe, ^{135}Xe, ^{41}Ar.

Sanitary building airborne release monitoring system

The system is used to check the exhaust ventilation systems in the healthcare building. The system consists of a continuous α- and β-emitting aerosol meter and a continuous radioiodine meter connected in series with it.

Laboratory samplers for release monitoring at chimneys

The laboratory sampling system is suitable for continuous sampling of aerosols and noble gases, radioiodes in various chemical forms, tritium and radiocarbon. The laboratory sampling system allows both operational and official sampling. A summary of the sample laboratory monitoring of radioactive substances is given in *Table 2.4.2.1-1*.

Combined sampling unit

The two main components of the equipment are the filter holder unit and the corresponding pump unit. Filters are placed in casings in the following order: an aerosol filter at the top, an elemental iodine filter underneath and a filter containing an activated carbon filter cartridge for organic iodine at the bottom. The built-in moisture separator ensures that filters for the binding of elemental iodine and organic iodine do not receive air in which water is present in the liquid phase. Sampling is continuous, aerosol and iodine filters are changed daily and weekly, iodine cartridges are changed weekly.

After sampling, the isotopic composition of aerosol and iodine filters and organic iodine-binding cartridges is determined by gamma spectrometry.

Tritium sampler

Sampling equipment custom developed 2 adsorption columns filled with molecular sieve. After filtering out aerosols, one column is used to bind HTO and the other column is used to bind HT after catalytic oxidation of hydrogen gas. There are 2 samplers per chimney.

The tritium activity concentration of chimney air from the processed samples is determined by liquid scintillation measurement technique.

Radiocarbon sampler

Sampling equipment: custom-developed device with 2 pcs bubbler columns. After the filtering of aerosols, one is used for the capture of carbon dioxide (CO_2) and the other for the capture of

carbon dioxide and hydrocarbons (C_nH_m + CO_2) after catalytic oxidation. There are 2 samplers per chimney.

The radiocarbon activity concentration of chimney air from the processed samples is determined by liquid scintillation measurement technique.

Noble gas samplers

There are two continuous samplers, one exchanged on working days for the laboratory determination of the air noble gas isotope composition and the other exchanged on a monthly basis for the laboratory determination of ^{85}Kr.

The isotopic composition is determined by gamma spectrometry and the ^{85}Kr activity is determined by proportional counting method.

Aerosols sampling

The aerosol filter in the filter holder unit pre-filters the air sample conveyed to the samplers described above. The filter is not included in the sampling program for routine tests, but can be used on demand, e.g. to check alpha emitters. Sampling is continuous, filters are changed on a monthly basis.

Sanitary building sampling system

There is a separate sampling branch, 14 in total, for each of the outputs of the ventilation system in the healthcare building in the primary circuit. Some of the ventilation systems with a technological filter line have a continuous monitoring system, while others are sampled with an aerosol and iodine filter. Sampling is continuous, filters are changed on a quarterly basis, if the telemetry system shows a higher value than the background, immediate filter change is carried out.

After sampling, the isotopic composition of aerosol and iodine filters is determined by gamma spectrometry and radiostrontium determination is performed on a quarterly basis.

2.4.2.1.2. Monitoring of liquid release

The discharge of the waters of the Paks NPP containing radioactive substances is subject to an authorization based on laboratory measurements. Liquid releases are monitored by telemetry detectors installed on different discharge routes and by installed automatic samplers.

Telemetry system for monitoring liquid releases

The water used is discharged from the power plant to the receiver via two routes: the warm-water channel and the pipeline discharging the treated faecal waters and the above-balance waters. Both the water of the warm-water channel and the water of the discharge line are checked by a water metering station at their end points (station V2 and V3). Regarding the fact that the water in the warm-water channel is practically water taken from the Danube through the cold-water channel, the incoming water is monitored by a station installed next to the cold-water channel (V1) in order to correctly interpret the release values.

At stations V1 and v2, water extracted from the channel with a submersible pump circulates in a measuring vessel of 400 dm^3 with a lead shielding of 5 cm, while at the station V3 measuring the more active medium, the measuring vessel is of 30 dm^3. The tempered scintillation detector head ø65x65 mm placed in a protective tube in the approximately geometric centre of the vessel measures the total γ-activity concentration of water over 10-minute time cycles. At the station V3, the total γ-activity concentration is monitored by a measuring equipment with a similar structure and parameters. Depending on the water discharge, water from the tank installed next to the discharge line enters the station's wet room via a priority water pipeline with a submersible pump operating intermittently. Here the water flows through a cylindrical container with a volume of 30 dm^3, a bottom conical formation and a 5 cm wall thickness with lead protection. At water metering stations, local computers collect data, pre-process and communicate with central SCADA computers.

A monitoring system for groundwater contamination has been established. The purpose of the tests, based on the detection of radioactive contaminations and the measurement results, is to determine the leakage sites using the impurity propagation model. The monitoring system consists of a network of groundwater monitoring wells, which is made up of 20 continuous samplers and 15 automatic water level recorders installed in the monitoring wells, and 35 wells sampled on a monthly and a quarterly basis. The 20 wells with continuous samplers are sampled by sampling columns containing special cation and anion exchange resins for laboratory tests (isotopic selective measurements), while only ^{3}H activity concentrations are determined from samples from other wells.

Sampling of liquid releases

Above-balance and wastewaters generated during the operation of the NPP are collected in monitoring tanks before discharge. In all cases, the discharge of water is preceded by strict chemical classification. A decision on the release of water shall be made on the basis of measurements of total β-activity concentration and pH of the samples taken from the monitoring tanks. The isotope-selective, accurate emission data are then determined by processing and laboratory measurement of the average samples obtained by archiving the samples weekly, monthly and quarterly.

Above-balance water tanks are sampled for marking into a 5-litre sampling vessel. Total-β-activity is measured from the samples and total-α-activity concentration is determined in the case of one tank, resulting in a decision on the releasability of the water.

Laundry, laboratory and shower water (01XZ) are collected in separate tanks. All-β-activity is measured from the samples, resulting in a decision on the releasability of the water.

Other process waters (RJ and RZ) are sampled into a 2 litres sampling vessel. Total β activity is measured from the samples, resulting in a decision on the releasability of the water.

2.4.2.1.3. Measurement methods used

The measurement methods used are as follows:

- Total beta radiation measurement: plastic crystalline scintillation detector, low background gas flow proportional counter,
- Measurement of soft beta emitters: low background liquid scintillation analyser,
- Measurement of gamma-ray emitters: high purity germanium (HPGe) semiconductor spectrometry measurement system,
- Total alpha radiation measurement: surface barrier (PIPS) detector.

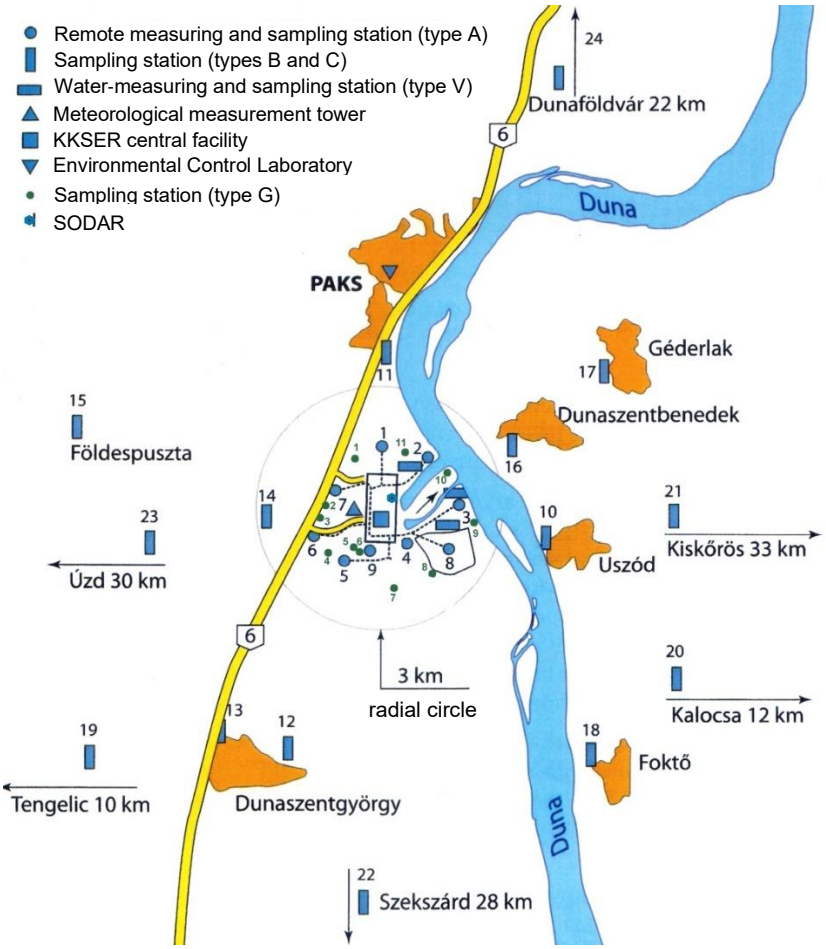
Further alpha and X-ray spectrometry measurements are carried out in an accredited laboratory on a contractual basis.

2.4.2.2. Operation and structure of the environmental monitoring system

One of the tasks of the in-site environmental radiation monitoring of the NPP is to demonstrate by direct measurements that the power plant, in normal operation, has less environmental impact with radioactive isotopes and radiation than the acceptable value. It is also responsible for contributing to the detection of technological malfunctions endangering the environment, in particular by measuring them on the site, and for monitoring the non-occurrence of environmental hazards once they have been eliminated. Finally, in order to assess the environmental consequences of a possible failure and to provide the basis for interventions affecting the population, it shall provide reliable data on the radiation status of the environment quickly.

In order to control the radioactive load on the environment, the Paks NPP operates a comprehensive radiation monitoring system in the operating environment (ÜKSER). The system consists of telemetry networks on the one hand, and laboratory sampling tests on the other.

The structure of the installed radiation monitoring system is shown in *Figure 2.4.2.2-1.*



Source: László Manga, István Apáthy, Sándor Deme, Attila Hirn, András Lencsés, Tamás Pázmándi: Analysis of environmental dose data of the Paks NPP, Radiation protection Online journal, VIII. Year, Issue 1, 2015.

Figure 2.4.2.2-1. Schematic drawings of the atmospheric release

Type A and B stations are used to measure the environmental radiation effects of radionuclides released into the atmosphere. Measurement of very low radiation levels in normal operation requires a highly sensitive system, while accident levels require high measurement limits and immediate availability of data, i.e. telemetry measurement. The objectives reflect this duality, with 9 Type A and 1 Type B stations meeting these requirements. In order to better cover the area, a further 11 G-type stations measuring γ-dose rate have been installed among the A-type stations.

Functions of Type A and Type B stations:

- measurement of the dose rate of γradiation,
- measuring the total β activity concentration of aerosols,
- measurement of the elemental and organic phases of iodine isotopes,
- aerosol and iodine sampling for laboratory measurements,
- air-sampling to determine ^{3}H and ^{14}C,
- fall-out sampling,
- the collection, processing and transmission of measured data.

The probe type BITT is used to measure the dose rate of γradiation. The wide measuring range (30 nSv·h^{-1}-10 Sv·h^{-1}) allows to monitor minor changes in natural environment radiation, as well as to measure high dose rates.

A plastic scintillator with the measuring range of $6 \cdot 10^{2}$-$5 \cdot 10^{7}$ Bq·m^{-3} is used to measure the total ß-activity of aerosols, the same detector is used to measure elemental iodine isotopes. The γ-radiation of organic phase iodine isotopes is measured with a NaI(Tl) scintillation spectrometer with a measurement range of $6 \cdot 10^{3}$-$5 \cdot 10^{7}$ Bq·m^{-3}.

The Type G station γ-probe is identical to the probe type BITT used in the Type A station. The power is supplied by a local battery. The treatment-free operation of the batteries is ensured by solar panels through the charging control unit. The transmission of the measured data is carried out by means of radio data transmission.

There are also so-called Type C stations, where dose measurements are carried out with TL dosimeters, and the evaluation is carried out on a monthly basis. If necessary, soil, grass and fall-out samples can be collected at these stations.

Table 2.4.2.2-1. demonstrates the tests used in the on-site radiation monitoring by sampling in the surroundings of the NPP is by the tests carried out in 2023.

The measurement methods used are as follows:

- total beta radiation measurement: low background gas flow proportional counter,
- measurement of soft beta emitters: low background liquid scintillation analyser,
- measurement of gamma-ray emitters: high purity germanium (HPGe) semiconductor spectrometry measurement system,
- on-site measurements: portable high purity germanium (HPGe) detector, portable dose rate meter,
- Dose measurement: thermoluminescent (TL) measuring system,
- Total alpha radiation measurement: surface barrier (PIPS) detector.

Further alpha-spectrometry, radio strontium and radiocarbon measurements are carried out in an accredited laboratory on a contractual basis.

Table 2.4.2.2-1. Tests used in the on-site radiation monitoring by sampling in the surroundings of the NPP in 2023

Sample type	Sampling site (change) time	Number of measure-ments per year	Processing		Measurement		Detection limit
			Method	Sample size, geometry	Method	Time [s]	
Aerosol (iodine telemeter)	10 (A1-A9, B24) weekly	–*	–	∅ 25 mm	gamma-spectrometry	20,000	5 mBq/m^3
Elemental iodine (iodine telemeter)	10 (A1-A9, B24) weekly	–*	–	∅ 25 mm	gamma-spectrometry	20,000	5 mBq/m^3
Organic iodine (iodine telemeter, activated carbon)	10 (A1-A9, B24) monthly	–*	boxing	∅ 60*50 mm	gamma-spectrometry	20,000	5 mBq/m^3
Aerosol (large volume)	10 (A1-A9, B24) weekly (B24) monthly	520 12	boxing radiochemical (^{90}Sr)	40*40*10 mm	gamma-spectrometry beta counting	50,000 3,000	5 µBq/m^3 1 µBq/m^3
Elemental iodine (large volume)	10 (A1-A9, B24) monthly	12-120	boxing	40*40*10 mm	gamma-spectrometry	50,000	5 µBq/m^3
Organic iodine (act. carb.) (large volume)	10 (A1-A9, B24) monthly	120	boxing	Marinelli	gamma-spectrometry	50,000	20 µ Bq/m^3
Air HT, HTO	10 (A1-A9, B24) monthly	240	desorption	20 cm^3 cuvette	liquid scintillation counting	18,000	1 mBq/m^3
Air CO_2, C_nH_m	10 (A1-A9, B24) monthly	240	chemical separation	proportional counter tube	beta counting	50,000	0.1 mBq/m^3
Fall-out	10 (A1-A9, B24) monthly	120	evaporation to dryness	35*35*5 mm	gamma-spectrometry	50,000	0.2 Bq/m^2
Soil	10 (A1-A9, B24) every six months 14-10 (operational area) yearly	20 14 10	drying, pulverization homogenization radiochemical (^{90}Sr) microwave acid digestion	Marinelli (~1-2 kg) ∅ 50 mm bowl	gamma-spectrometry beta counting alpha-spectrometry	20,000 10,000	0.5 Bq/kg 0.5 Bq/kg 0.01 Bq/kg
Grass	10 (A1-A9, B24) Quarter II. and IV.	20 20	drying, pulverization homogenization radiochemical (^{90}Sr)	Marinelli (~0,4 kg) ∅ 50 mm bowl	gamma-spectrometry beta counting	80,000 10,000	0.5 Bq/kg 0.5 Bq/kg
Dose TLD	26 (A, B, C, L, OMSZ) monthly	312	–	Al_2O_3 tablet	TL evaluation	300	5 µSv/month (5 nGy/h)
On-site measurement	10 (A1-A9, B24) yearly	10 10	–	in situ (soil surface) 1 m from soil surface	gamma-spectrometry dose rate	5,000 60	30 Bq/m^2 5 nGy/h

Sample type	Sampling site (change) time	Number of measure-ments per year	Processing		Measurement		Detection limit
			Method	Sample size, geometry	Method	Time [s]	
On-site measurement	8 (operational area) yearly 26 (operational area) in every six months	8 52	–	in situ (soil surface) route monitoring	gamma-spectrometry dose rate	5,000 5,000	30 Bq/m^2 50 nGy/h
Groundwater	52 wells monthly T58, V205 quarterly	628 120 120 ad-hoc	distillation (^{3}H) ion exchange separation, reg. ion exchange separation, reg. (^{14}C) ion exchange separation, reg. (^{90}Sr)	20 cm^3 cuvette ∅60 x 30 mm prop. count. ∅ 50 mm bowl	liquid scintillation gamma-spectrometry beta counting beta counting	18,000 50,000 50,000 50,000	2.0 Bq/dm^3 0.005 Bq/dm^3 0.001 Bq/dm^3 0.001 Bq/dm^3
Fishponds (water)	4 (designated 4 lakes) quarterly	16 16 4	evaporation (300 cm^3) distillation (^{3}H) form an annual average (4 dm^3)	∅ 60 mm bowl 20 cm^3 cuvette 35 x 35 x 5 mm	total beta measurement liquid scintillation gamma-spectrometry	10,000 18,000 50,000	0.05 Bq/dm^3 2.0 Bq/dm^3 0.01 Bq/dm^3
Swale (Water)	4 (designated points) quarterly Faddi árok monthly	16 16 12 5	evaporation (300 cm^3) distillation (^{3}H) form an annual average (4 dm^3)	∅ 60 mm bowl 20 cm^3 cuvette 35 x 35 x 5 mm	total beta measurement liquid scintillation gamma-spectrometry	10,000 18,000 50,000	0.05 Bq/dm^3 2.0 Bq/dm^3 0.01 Bq/dm^3
Industrial lime/chemical pools (water)	quarterly	8 8 2	evaporation (300 cm^3) distillation (^{3}H) form an annual average (4 dm^3)	∅ 60 mm bowl 20 cm^3 cuvette 35 x 35 x 5 mm	total beta measurement liquid scintillation gamma-spectrometry	10,000 18,000 50,000	0.05 Bq/dm3 2.0 Bq/dm3 0.01 Bq/dm3
Danube water	2 (2 designated points) yearly	2 2 2	evaporation (20 dm^3) distillation (^{3}H) ion exchange separation, reg. (^{90}Sr)	35 x 35 x 5 mm 20 cm^3 cuvette ∅ 50 mm bowl	gamma-spectrometry liquid scintillation beta counting	50,000 18,000 50,000	0.005 Bq/dm^3 2.0 Bq/dm^3 0.001 Bq/dm^3

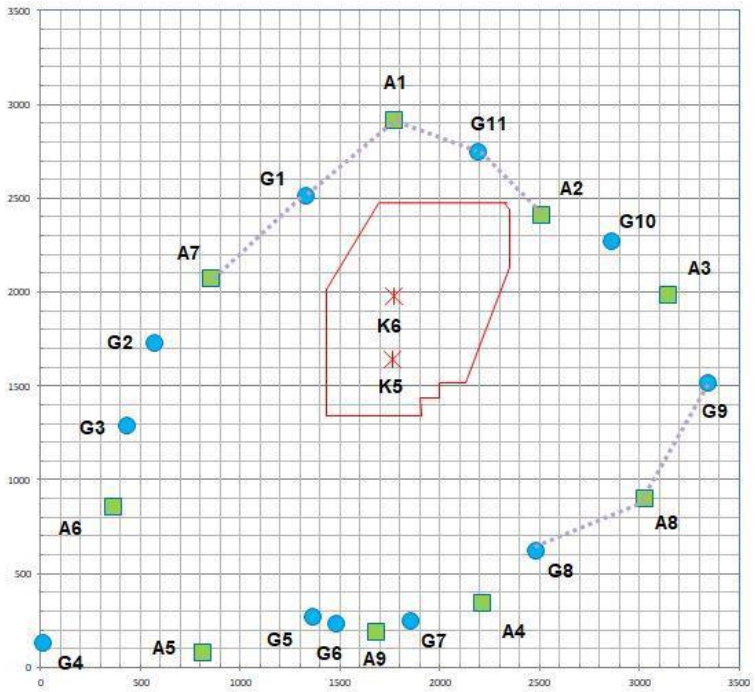
Sample type	Sampling site (change) time	Number of measure-ments per year	Processing		Measurement		Detection limit
			Method	Sample size, geometry	Method	Time [s]	
Danube mud	3 (3 designated points) every six months	6 6	drying, pulverization homogenization radiochemical (^{90}Sr)	Marinelli (~2 kg) ∅ 50 mm bowl	gamma-spectrometry beta counting	20,000 10,000	0.5 Bq/kg 0.5 Bq/kg
Fishponds (mud)	4 (4 designated points) yearly	4	wet homogenization	Marinelli (~2 kg)	gamma-spectrometry	20,000	0.5 Bq/kg
Swale, Faddi árok (mud)	4 (4 designated points) every six months	8	wet homogenization	Marinelli (~2 kg)	gamma-spectrometry	20,000	0.5 Bq/kg
Industrial lime	2 (2 pools) every six months	4	wet homogenization	Marinelli (~2 kg)	gamma-spectrometry	20,000	0.5 Bq/kg
Fecal sludge	10 (dewatering units)	ad-hoc	boxing	Marinelli (~2 kg)	gamma-spectrometry	5,000	2.0 Bq/kg
Milk	1 (designated farm) monthly	12	boxing	Marinelli (1.5 dm3)	gamma-spectrometry	50,000	0.5 Bq/dm3
Fish	2 (from 4 designated lakes) one in a quarter	4 4	ready-to-cook raw meat meat offal	Marinelli (~1 kg) 65*30 mm	gamma-spectrometry	50,000 50,000	0.5 Bq/kg 10 Bq/kg

* Sample exchange on a regular basis, measurements performed only in exceptional cases (e.g. in case of accidents).

2.4.2.3. Modification of the monitoring system

According to the Preliminary Safety Analysis Report of Paks II NPP to be built in the immediate neighbouring of the Paks NPP, the Paks NPP's environmental monitoring system is basically suitable for the environmental radiological monitoring for the combined releases of the two power plants, but some changes are needed.

The location of the main monitoring stations of the existing release and environmental radiation monitoring system (KKSER) is shown in *Figure 2.4.2.3-1.* The system is a network of different types of telemetry stations.



Source: Paks II NPP Preliminary Safety Analysis Report, Radiation protection program, 2022

Figure 2.4.2.3-1. Schematic drawing of the monitoring system of atmospheric releases and the environment

The new NPP units will be located north of the operating units. Analysis and calculations of air and wind movements have shown that the location of the existing network of measuring stations is not favourable for new units and their ventilation chimneys. In order to ensure proper environmental monitoring of Paks II NPP Units 5-6, it is necessary to increase the number of Type G stations complementary to the measurements of the Type A stations and located between them.

The distance between stations A7 and A1 is so large due to the new ventilation chimneys that the coverage is not sufficient to obtain reliable results of aerosol and iodine activity measurements despite the availability of Type G stations. Therefore, it is advisable to create a new Type A station (A10) in place of G1 station. G1 Station, on the other hand, is shifting southwest. G1a Station (new) would be located between A10 station (new) and A1 station (existing). G11 Station shall be moved northwest and G11a station (new) shall be between G11 station and A2 station. G8 and G9 stations are shifted south and northeast respectively (*Figure 2.4.2.3-2.*).



Source: Paks II NPP Preliminary Safety Analysis Report, Radiation protection program, 2022

Figure 2.4.2.3-2. Proposal for the development of existing release and environmental radiation protection monitoring system telemetry stations

3. Identification of the impact factors and the assessment area (potential impact area)

3.1. Determination of impact factors and impact processes

The fundamental purpose of examining environmental impacts is to predict and assess the changes that will occur in certain elements / systems of the environment as a result of the planned activity, based on the changes that will occur in the ultimate recipients of the impacts. To assess the impacts, it is first necessary to identify the impact factors of the planned activity, as well as the possible direct and indirect impacts resulting from them – that is, the potential impact pathways.

To determine the impact factors and impact processes during environmental impact investigation, the analysis is conducted in relation to the individual phases of the planned activity (construction, operation, decommissioning). In this case, the construction phase corresponds to the implementation of the preparatory activities for the SSLE. The operational phase covers the 20-year duration of the SSLE. However, the decommissioning and dismantling of the NPP is an activity that requires an independent impact assessment under legal regulations, and therefore the assessment of the impacts of decommissioning is addressed only in principle in *Chapter 6*.

Based on the above, it is necessary to analyse in detail the preparatory activities for the SSLE and the operation of the NPP with regard to the contributing impact factors and impact processes.

3.1.1. Environmental impact factors of the preparation for the SSLE

Among the activities planned as part of the preparation of the SSLE, as described in *Chapter 2.2.2.*, the interventions that must be taken into account – as they represent significant environmental impact factors and therefore require detailed examination – include the construction of the alternative warm-water channel and peak cooling system, as well as other reconstruction works affecting the NPP's mechanical, electrical, instrumentation and control systems, as well as its structures.

Activities related to the construction of the alternative warm-water channel section, the associated structures, and the cooling cell cooling system, which may be considered as the following impact factors:

- the land occupation required for the mobilisation and construction works (storage of temporary structures, construction materials, structural materials, and heavy equipment; establishment of work areas), which also extends to the protected Natura 2000 site,
- site preparation work (clearance of vegetation), construction and installation work (dust generation, exhaust gases from transport and construction vehicles, noise and vibration exposure, disturbance, and the presence of construction workers),
- the transport of construction materials and workers to the construction site, and the removal of waste generated (dust, exhaust gases from transport and loading machinery, noise and vibration exposure, disturbance, and deterioration of roads),
- waste generated during construction work (municipal, hazardous, and non-hazardous industrial waste),
- the appearance of new buildings on the power plant site.

Most significantly, the impact of land occupation – which also affects protected areas – is substantial, while the effects of air pollution, noise pollution, and waste generation are temporary during the construction period.

The potential environmental impact factors associated with the construction of the alternative warm-water channel section and its related structures, as well as the cooling cell system, and the preparation of the cooling system site – which must be taken into account in the environmental impact investigation – and the potential impacts they may cause are summarized in *Table 3.1.1-1*.

The impact factor to be examined in the EIA in connection with other reconstruction works affecting the mechanical, electrical, and instrumental and control systems, as well as the

structures of the NPP is waste generation (municipal, hazardous, and non-hazardous industrial waste). In the event of an emergency event (e.g., spillage during waste transport), the affected environmental medium is the soil and geological medium, and the potential direct impact is accidental soil contamination.

Table 3.1.1-1. Environmental impact factors, direct and indirect potential impacts, associated with the construction of the alternative warm-water channel section and related structures, and the preparation of the cooling system area

Affected environmental medium or system	Impact factor	Possible direct impact	Possible indirect impact
Air	Construction work (dust formation, exhaust releases from construction machinery)	Temporary deterioration of air quality in the immediate vicinity	Health effects, changes in living conditions for humans and biosphere
	Transportation of construction materials and workers to the construction site; removal of construction waste (dust generation, exhaust releases from transport vehicles)	Temporary deterioration of air quality in the immediate vicinity and along access roads	Health effects, changes in living conditions for humans and biosphere
Surface water and groundwater	Filling of construction sites, build-up of open spaces, new earthworks, construction of embankments, concrete basins, pipeline construction, and installation of underground cables	The reduction in the area of fish ponds, and changes in the conditions of runoff, infiltration, and evapouration within the construction area and its vicinity	Changes in land use, changes in the living conditions of biosphere
	Water extraction from the Danube (to meet technological water requirements, e.g., for concrete work, if the concrete is not delivered ready-mixed)	Temporary decline in volume	Restrictions on use
	Generation of conventional wastewater	Temporary changes in surface water quality	Restrictions on use, health and environmental risks
	Release of pollutants (e.g., hazardous substances) from machinery and transport vehicles in the event of an emergency event	Water pollution	Restrictions on use, health risks, changes in living conditions
Soil, geological medium	Land acquisition for mobilization and construction work	Temporary land use	Restrictions on use, changes in the living conditions of biosphere
	Filling of construction sites, new earthworks, embankments, and construction of structures	Changes in soil characteristics and structure, terrain conditions, and elevation levels	Restrictions on use, changes in the living conditions of biosphere
	Construction work, earthmoving, operation of heavy machinery, landscaping, road construction	Changes in soil quality	Restrictions on use, changes in the living conditions of biosphere
	Emergency event related to the handling of conventional waste (e.g., spills)	Soil contamination	Restrictions on use, health risks, changes in living conditions

Affected environmental medium or system	Impact factor	Possible direct impact	Possible indirect impact
	Release of pollutants (e.g., hazardous substances) from machinery and transport vehicles in the event of an emergency event	Soil contamination	Restrictions on use, health risks, changes in living conditions
Biosphere, ecosystems	Land acquisition, clearing of existing vegetation, filling of the construction site	Habitat loss in the area enclosed by existing and new warm-water channels and in the Natura 2000 site in the floodplain; a decline in the extent of the floodplain forest; the crossing of the protected natural area; and the obstruction of migration due to the physical barrier created by the new channel	Migration, deterioration of conditions, decline in biodiversity, changes in the conditions for nature conservation
	Construction work (dust, exhaust gases, disruptive noise)	Deterioration of living conditions	Migration, temporary changes in living conditions
Urban environment	Construction work (appearing construction workforce), related activities (e.g., transportation)	Changes in consumption, infrastructure needs, and the condition of man-made structures (roads, infrastructure elements)	Possible changes in usage, changes in living conditions
	Waste generation during construction work (municipal, hazardous, and non-hazardous industrial waste)	Waste storage, transportation, and disposal	Possible changes in usage
	Construction work (noise and vibration emissions from construction machinery)	Disturbance, health risks, deterioration of buildings and structures	Restrictions on use, deterioration in quality of life
	Building materials and workers, transportation of waste generated (noise emissions from transport vehicles)	Disturbance, health risks, deterioration of buildings and structures	Restrictions on use, deterioration in quality of life
Landscape	Land use associated with mobilization and construction works (changes in vegetation cover)	Restrictions on land use, visual disturbance of the landscape	Restrictions on Use

3.1.2. Environmental impact factors of operation during the SSLE

Given that, in this case, the impact assessment concerns an existing and operational facility, the operational impact factors and impact processes are essentially the same under current conditions and in the event of the SSLE. In addition to the known environmental impact factors associated with current operations, the noise emissions and heat releases into the ambient air from the artifical-draft wet cooling cell system must be taken into account as new impact factors. In terms of thermal load on the Danube, the discharge of warmed cooling-water into the river remains the key 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 pollutants and noise emissions as environmental impact factors, it is necessary to take into account the atmospheric and noise emissions resulting from the operation of the replacement diesel generator for Units 1 and 2, which represent a new source of emissions. The environmental impact factors associated with the operation of the NPP are as follows:

- Land occupation, land use – certain areas within the site will be built on due to the structures of the alternative warm-water channel and peak cooling system; otherwise, there will be no changes during the extended service life period.
- The existence of the facility (electricity production activity, its role in retaining residents in the community, impact on the landscape).
- Operation – all loads (radiological and conventional), emissions (load on environmental components, changes in quantity).
- Transportation (delivery of operational personnel, operational supplies, tools, machinery, and equipment; removal of waste, which involves air pollution, noise emissions, and disturbances).
- Technological water extraction from the Danube (changes in the quantity of surface water).
- Drinking water extraction from the Csámpa waterworks (changes in the quantity of groundwater).
- Extraction of cooling-water and discharge of warmed cooling-water into the Danube (thermal load, hydraulic/hydro morphological changes).
- Discharge of dredged material from the cold-water channel into the Danube (hydrological and water quality impacts, impacts on aquatic biosphere),
- Generation and treatment of wastewater and stormwater (changes in quantity and quality in the receiving body).
- Generation, temporary storage on site, removal, and management of waste (conventional and radioactive waste).
- The generation of spent fuel assemblies.

The potential environmental impacts of any malfunctions, or emergency events that may occur during operation are as follows:

- Failures of operational systems and equipment that could result in the release of radioactive and conventional contaminants into the environment (e.g., breakage of pipelines; release of contaminants – such as oils and chemicals – onto the ground or into the geological medium due to failures in the turbine oil system, transformers, tanks, and pipelines).
- Release of pollutants into surface water, groundwater and soil due to malfunctions in operational systems and equipment (such as the improper operation of industrial wastewater, or municipal sewage treatment systems).
- Air pollutant and noise emissions from the operation of diesel generators during power outages.
- Loading of the soil or geological medium during waste storage, handling, and transport, including spillage and leakage.
- Loading of the geological medium resulting from malfunctions or accidents during the delivery and internal transport of hazardous substances.
- Waste generation during damage mitigation (surplus above normal operations).

Table 3.1.2-1. lists the most important impact factors associated with the existence and operation of the NPP, as well as potential malfunctions and emergency events, along with their direct and indirect potential impacts, grouped by the relevant environmental media and systems (air, water, geological medium, biosphere, and the built environment).

Table 3.1.2-1. Environmental impact factors of the Paks NPP's operation, and its direct and indirect potential impacts

Affected environmental medium or system	Impact factor	Possible direct impact	Possible indirect impact
Air	Atmospheric releases of radioactive materials during normal operation	Changes in environmental radioactivity; radiation exposure of the population and biosphere	Increased health and environmental risks

Affected environmental medium or system	Impact factor	Possible direct impact	Possible indirect impact
	Releases of conventional air pollutants (from power plants and transportation) during normal operation	Changes in air quality in the immediate vicinity and along access roads	Health effects, changes in living conditions for humans and biosphere
	Heat releases into the atmosphere (normal operation)	Changes in the air temperature of the immediate environment	Changes in local climatic conditions, changes in living conditions
	Presence of the power plant (built-up area)		
	Emergency (radioactive) and emergency event (conventional) air pollution	Environmental radioactivity increases beyond background levels	Increased health risks; deposition of radioactive materials in the soil and surface waters
		Increase in the concentration of conventional pollutants in ambient air	Health and ecological impacts
Surface water and groundwater	Water extraction (to meet water demand for cooling, technological and other purposes	Changes in water quantity in surface and groundwater, hydro morphological changes	Restrictions on use, changes in the structure of aquatic biosphere
	Release of radioactive materials (liquid)	Changes in surface water quality	Increased health risks, restrictions on use
	Conventional wastewater generation – pollutant discharge	Changes in surface water quality	Restrictions on use, health and ecological risks
	Discharge of warmed cooling-water	Increase in the temperature of the receiving water body; hydraulic and hydro morphological changes; changes in the structure of aquatic biosphere	Temporary disturbance of land uses, cascading impacts of changes in material flow processes within ecological communities, graduation of invasive species, and microclimatic changes
	Discharge of dredged material from the cold-water channel into the Danube	Changes in hydrology and water quality	Impacts on aquatic biosphere
	Accidental water pollution	Pollution in receiving water bodies or groundwater; changes in the living conditions of aquatic biosphere	Temporary restrictions on certain uses
Soil, geological medium	Emergency events related to the handling of conventional waste (e.g., spillage)	Soil contamination	Restrictions on use, health risks, changes in living conditions
	Release of pollutants (e.g., hazardous materials stored on site, radioactive isotopes/waste, wastewater) in the event of an emergency event	Soil contamination	Restrictions on use, health risks, changes in living conditions
Biosphere, ecosystems	The presence (built-up area) and operation of the power plant, as well as the impact factors affecting other environmental media (pollutant emissions, noise emissions, etc.)	Changes in living conditions	Migration, deterioration of conditions, decline in biodiversity, changes in the conditions for nature conservation

Affected environmental medium or system	Impact factor	Possible direct impact	Possible indirect impact
	Release of pollutants (into the air, water, or soil) in the event of an emergency event	Damage to biosphere species and their habitats	Deterioration of conditions, decline in biodiversity
	Light emissions from outdoor lighting at night	Changes in living conditions	Migration, loss of biodiversity
Urban environment	Presence, operation, and related activities of a power plant (e.g., transportation)	Impacts on the operation and development of the municipality	Possible changes in usage
		Changes in the condition of man-made elements (roads, infrastructure elements)	Changes in living conditions
	Noise and vibration emissions	Disturbance, health risks, deterioration of buildings and structures	Restrictions on use, deterioration in quality of life
Landscape	Presence of the power plant (built-up area)	Restrictions on land use, landscape disturbance	Restrictions on use

3.2. Delimitation of the assessment area

The delimitation of the assessment area followed the approach used in previous similar environmental impact investigations conducted for the facilities at the Paks site (the first service life extension for the Paks NPP and the construction of Paks II NPP). With the commissioning of the Paks II NPP, the combined effects of the two facilities must now be taken into account; the impact assessment addresses this as well, which in turn determined the boundaries of the assessment area. The operation of the two facilities simultaneously was also taken into account in the EIA for Paks II NPP, so the assessment area defined therein provided an appropriate basis for the SSLE of the Paks NPP as well.

The area to be examined is divided into the normal operating zone and the zone where impacts are expected in the event of malfunctions or emergency events. When defining the area to be investigated, the three-tiered zoning system used in the field of radiology – namely, the 500-metre zone (the safety zone, immediate environment), the 5-10-kilometre zone (nearby environment), and the 30-kilometre zone (wider environment) – may be taken into account.

In the baseline assessment, when describing the host region and its general characteristics, it was appropriate to start with the conditions of the 30-kilometre radius. However, when presenting the current status in greater detail across specific fields, the assessment area could be narrowed down to focus on the immediate environment. In the case of the assessment of transboundary environmental impacts, the assessment area extended beyond the generally accepted 30-kilometre radius for certain environmental impact factors.

Based on the above criteria, the assessment area considered in the impact assessment covers the following regions:

- The site and its immediate environment (the NPP's safety zone, a distance of 500 m measured from the plane of the outermost technological protection wall).
- The immediate environment, defined as the area within which conventional pollutant emissions, as well as environmental impacts and pressures, are estimated to extend at their maximum. This corresponds to a radius of approximately 5-10 km around the power plant.
- The wider environment, which is estimated to be the area within which radiological effects could cause detectable changes in the event of a malfunction, or where accumulation might be expected. This is a zone with a radius of up to 30 km.

In addition to the above, where a discipline-specific assessment warranted it (e.g., transboundary impacts), the assessment area was defined in accordance with the purpose of the assessment.

4. Current status of conventional environmental characteristics and changes expected as a result of the SSLE

4.1. Impacts on air quality

4.1.1. Air quality limit values and guideline values

The limit values and design guidelines used in the analyses of the effects on air quality were determined in accordance with Ministerial Decree 4/2011. (I. 14.) VM on limit values for air pollution levels and emission limit values for stationary point sources of air pollution. The health-based limit values for air quality are set out in Annex 1 to the Decree (*Table 4.1.1-1.*). For certain parameters, the regulation does not specify health-based limit values. Therefore, for these air pollutants, the design guideline values specified in Annex 2 of the Decree (*Tables 4.1.1-2.* and *4.1.1-3.*) were taken into account during the assessment.

The planning guideline is set forth in Ministerial Decree 4/2011. (I. 14.) VM, Section 2 (1) e), which states that in the planning of an activity, for the purpose of assessing air quality levels in the area under review, defining the activity's impact area and preparing dispersion models, the air quality level recommended for activities subject to an EIA or an integrated environmental permit shall apply; otherwise, the recommended air quality level.

Table 4.1.1-1. Health-based air quality limits

Air pollutant	Air quality limit [μg/m³]		
	Hourly	24-hour	Annual
Nitrogen-dioxide (NO_2)	100	85	40
Carbon-monoxide (CO)	10 000	5 000*	3 000
Particulate matter (PM_{10}) (particulate matter with a diameter of less than 10 μm)	–	50	40
Sulfur-dioxide ($SO_{2)}$	250	125	50
	Maximum 8-hour moving average concentration [μg/m³]		
Ozone (O_3)	120		

* Maximum 8-hour moving average concentration.

Table 4.1.1-2. Design guideline values for air pollutants

Air pollutant	Design guidelines [μg/m³]		
	Hourly	24-hour	Annual
Nitrogen-oxides (NO_x)	200	150	–
Total Suspended Particulate Matter (TSPM) (total suspended particulates)	200	100	–

Table 4.1.1-3. Design guidelines for settling dust

Air pollutant	Design guidelines	
	30 days [g/m², 30 days]	Annual [t/km², year]
Settling dust	16	120

4.1.2. Description of the environmental baseline

To describe the baseline air quality of the environment, the assessment area was first classified into air quality zones based on data from the relevant legislation. While these data cover a larger region, more precise, site-specific data were required to conduct the impact assessment.

Because the stations of the National Air Pollution Monitoring Network (OLM) are located far from the site, they do not provide adequate baseline data. It was therefore necessary to analyse the results of on-site measurement programs conducted in the vicinity of the Paks site. On the one hand, the results of measurement programs conducted in previous years were analysed; on the other hand, a field measurement program was carried out in 2024-2025 to determine current air quality, and the results of that program were also analysed and taken into account.

The background ambient air pollution data for the area surrounding the Paks NPP were derived by averaging the values of the air quality measurements recorded at each sample point (*Table 4.1.2-1.*). These background air pollution data were used as baseline air quality data.

Table 4.1.2-1. Ambient air baseline pollution taken into account in the Paks region

Year	SO_2 [μg/m³]	NO_2 [μg/m³]	NO_x [μg/m³]	CO [μg/m³]	O_3 [μg/m³]	Total suspended particulates (TSPM) [μg/m³]	Particulate matter (PM_{10}) [μg/m³]	Settling dust [g/m²×30 days]
Averaging time	hourly	hourly	hourly	hourly	8-hour *	hourly	24-hour	30 days
Concentration	4.3	10.3	17.7	670.3	67.7	35.2	19.5	7.7

* Maximum 8-hour moving average concentration.

4.1.3. Load-bearing capacity of the studied area

Air pollution data for ambient air in the vicinity of the site were collected, and the pollution levels of the ambient air were characterized and evaluated. Based on the evaluation of the measurement results, the area's pollution load limits were determined in accordance with Section 2 point 40 of Government Decree 306/2010. (XII. 23.) on air protection. The air pollution load capacity level was defined as the difference between the air pollution limit value and the baseline air pollution level.

Table 4.1.3-1. Load-bearing capacity of air in the Paks region

Air pollutant	Baseline air pollution	Air quality limit value	Load-bearing capacity	Reference period
	[μg/m³]			
Sulfur-dioxide (SO_2)	4.3	250	245.7	hourly average
Nitrogen-dioxide (NO_2)	10.3	100	89.7	hourly average
Nitrogen-oxides (NO_x)	17.7	200*	182.3	hourly average
Carbon-monoxide (CO)	670.3	10 000	9 329.7	hourly average
Ozone (O_3)	67.7	120	52.3	maximum of 8-hour moving averages
Particulate matter (TSPM)	35.2	200*	164.8	hourly average
Particulate matter (PM_{10})	19.5	50	30.5	24-hour average
Settling dust	7.7	16	8.3	g/m² × 30 days

* Design guideline.

4.1.4. Modelling of atmospheric pollutant dispersion

To calculate the atmospheric dispersion of air pollutants released into the air, determine the expected air quality, and delineate the affected areas, the comprehensive atmospheric dispersion modelling software AERMOD View 12.0 – developed by Lakes Environmental and based on a Gaussian plume model – was used. The steps of the model calculation were as follows:

- After running the atmospheric dispersion model, the concentration distribution of the emitted pollutants was visualized on a site plan and overlaid on an aerial photograph.
- The concentrations resulting from the activities were determined by comparing them to the air pollution limit values prescribed by Ministerial Decree 4/2011. (I. 14.) VM and the load-bearing capacity values derived from baseline studies. The impact areas were delineated in accordance with the provisions of Government Decree 306/2010. (XII. 23.).

4.1.5. Sources of air pollutant releases

In connection with the activities planned as part of the preparation for the SSLE of the Paks NPP, significant air pollutant releases are expected to result from the construction of the alternative warm-water channel section and the associated cooling cell peak cooling system. The sources of air pollutant releases from the construction of the new channel section and the peak cooling system are as follows:

- The area affected by the earthworks will serve as a diffuse source of air pollution due to dust emissions from the earthworks.
- Another major source of air pollution will be the machinery operating on the worksite, which pollutes the atmosphere with exhaust releases.

With regard to the operation of the NPP – specifically in terms of releases of conventional air pollutants – the sources of air pollution are the diesel generators located on the site.

The Paks NPP site houses several diesel generators that serve as emergency power sources; their exhaust manifolds operate as point sources of air pollution. Under normal operating conditions, diesel generators operate only in test mode. They are run for just a few hours at a time during specific periods each year. Diesel generators do not operate in parallel; they are not run simultaneously, so only one diesel generator is in operation at any given time.

Another source of air pollutant releases associated with the operation of the Paks NPP is transportation related to the facility's operations, including various categories of road vehicles such as passenger cars, light commercial vehicles, motorcycles, and buses.

During the period of joint operation of the Paks NPP and Paks II NPP, the primary sources of air pollutant releases during normal operation will also be the on-site diesel generators. These generators will only be operated for a few hours each year for testing purposes.

When the Paks NPP and Paks II NPP are in joint operation, air pollutant releases from traffic related to the two facilities must also be taken into account. The sources of air pollutant releases from traffic will also be motor vehicles belonging to various vehicle categories.

In the event of an emergency relevant to air pollutant releases, the sources of such releases will be the stacks of the three emergency diesel generators per unit (12 in total) at the Paks NPP.

4.1.6. Current Impacts of the NPP and expected changes resulting from the SSLE

The results of the analysis of the effects on air quality for the cases examined are as follows. The results of the analysis have been summarized in tabular form, and the figures show the trends in the concentration distribution of nitrogen-dioxide – the primary air pollutant.

The results of the studies on the construction of the alternative warm-water channel section and the peak cooling system are summarized in *Table 4.1.6-1*, while the calculated hourly concentration of nitrogen-dioxide is shown in *Figure 4.1.6-1*.

Table 4.1.6-1. Summary of the effects of implementing the alternative warm-water channel and peak cooling system on air quality

	Air pollutant			
	Nitrogen-dioxide (NO_2)	**Carbon-monoxide (CO)**	**Particulate matter (TSPM)**	**Particulate matter (PM_{10})**
Max. concentration [µg/m³]	173.0	1072.0	174.0	68.3
Exceeding the limit value	On the installation area.	None.	None.	On the installation area.
Exceeding load capacity	On the installation area.	None.	On the installation area.	Within the installation area and outside the installation area.
Impact Area	Within a radius of 1,100 metres from the source of releases, on the installation and operational site, and in areas outside the site	Within a 790-metre radius of the release source, on the installation and operational site, and in areas outside the site.	Within the installation area, and outside the installation area but within 200 metres of the site boundary.	Within the installation area, and outside the installation area but within 700 metres of the site boundary.
Description of impacts	The impacts will occur in the medium term – during the earthwork phase. The intensity of the impact will reach the threshold level, and these impacts will occur in a relatively small portion of the affected area.	The impacts will occur in the medium term – during the earthwork phase. The impact is neutral.	The impacts will occur in the medium term – during the earthwork phase. The intensity of the impact will reach the threshold level, and these impacts will occur in a relatively small portion of the affected area.	The impacts will occur in the medium term – during the earthwork phase. The intensity of the impact will reach the threshold level, and these impacts will occur in a relatively small portion of the affected area.

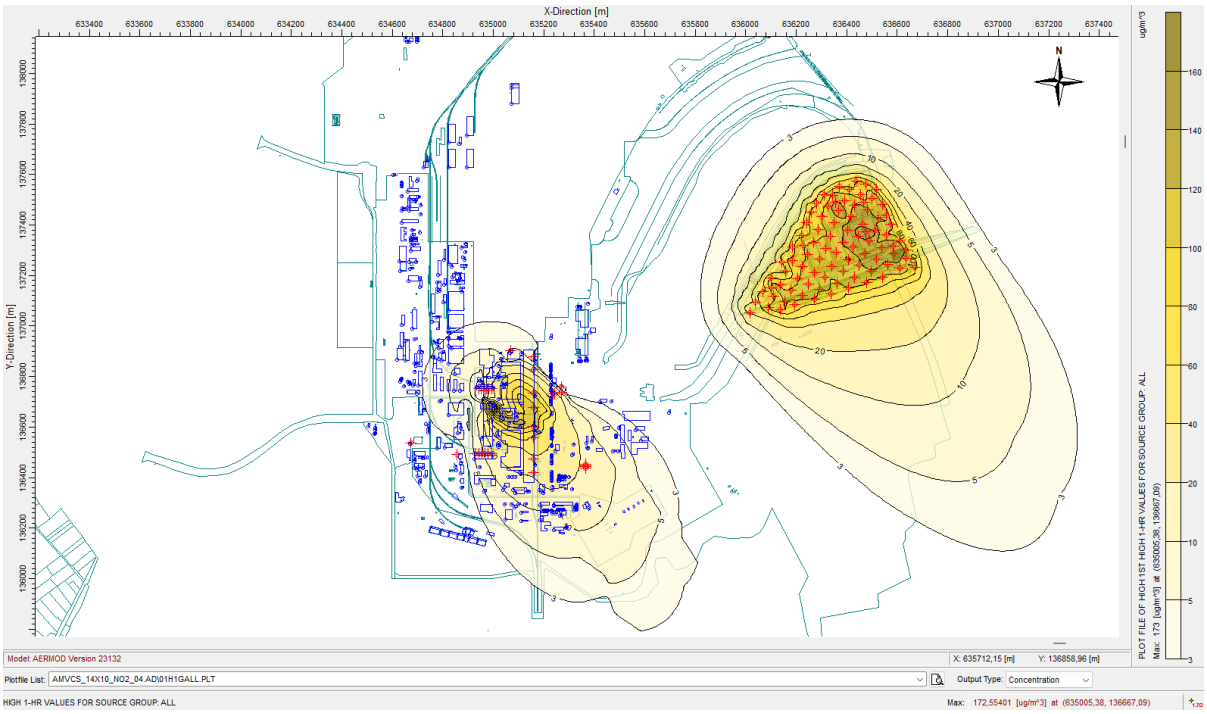


Figure 4.1.6-1. Hourly nitrogen-dioxide (NO_2) concentrations calculated for the construction phase of the alternative warm-water channel and peak cooling system

The results of the studies on the independent operation of the Paks NPP during the SSLE period are summarized in *Table 4.1.6-2.*, and the calculated hourly concentration of nitrogen-dioxide is shown in *Figure 4.1.6-2*.

Table 4.1.6-2. Summary of the effects of the independent operation of the Paks NPP during the SSLE period on air quality

	Air pollutant	
	Nitrogen-dioxide (NO_2)	**Carbon-monoxide (CO)**
Max. concentration [µg/m^3]	172.0	7.9
Exceeding the limit value	On the operational area.	None.
Exceeding load capacity	On the operational area.	None.
Impact Area	Areas within a 690-metre radius of the releases, including both on-site and off-site areas.	Areas within a 280-metre radius of the releases, including both on-site and off-site areas.
Description of impacts	The intensity of the impact will reach the threshold level. However, these impacts will occur only periodically and in a relatively small portion of the affected area.	The effects on carbon-monoxide releases will be neutral.
Description of impacts	The intensity of the impact will reach the threshold level. However, these impacts will occur only periodically and in a relatively small portion of the affected area.	The effects on carbon-monoxide releases will be neutral.

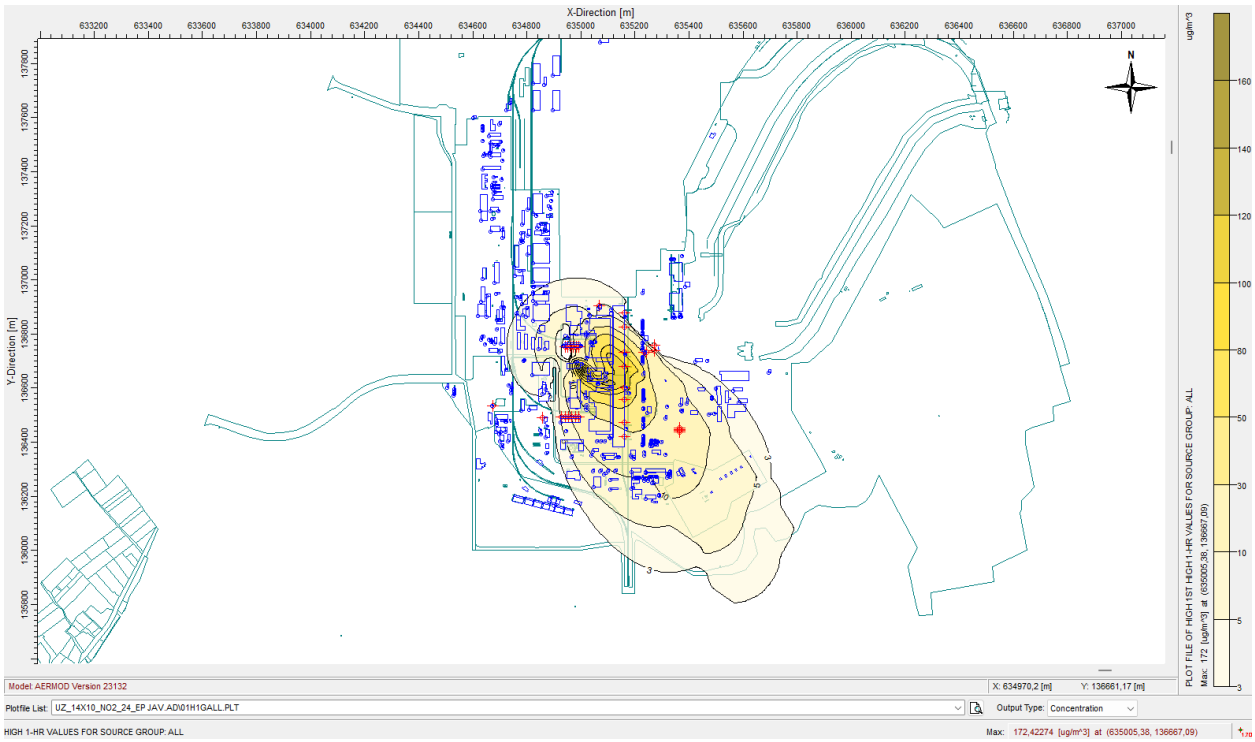


Figure 4.1.6-2. Hourly nitrogen-dioxide (NO_2) concentrations calculated for the independent operation of the Paks NPP during the SSLE period (during the trial operation of the diesel generators)

The results of the studies on the impact of traffic associated with the operation of the Paks NPP during the SSLE period are summarized in *Table 4.1.6-3.*, while the calculated hourly concentration of nitrogen-dioxide is shown in *Figure 4.1.6-3*.

Table 4.1.6-3. Summary of the impact of traffic related to the operation of the Paks NPP during the SSLE period on air quality

	Air pollutant	
	Nitrogen-dioxide (NO_2)	**Carbon-monoxide (CO)**
Max. concentration [µg/m³]	22.2	58.7
Exceeding the limit value	None.	None.
Exceeding load capacity	None.	None.
Impact area	Within 30 metres of the edge of the roadway along the southern access road to the Paks NPP. Within 20 metres of the edge of the roadway along the section of Main Road No. 6 between the southern access road to the Paks NPP and the Paks-Kölesdi Road intersection.	Along the southern access road to the Paks NPP, within 10 metres of the edge of the roadway.
Description of impacts	The impacts will be neutral.	The impacts will be neutral.

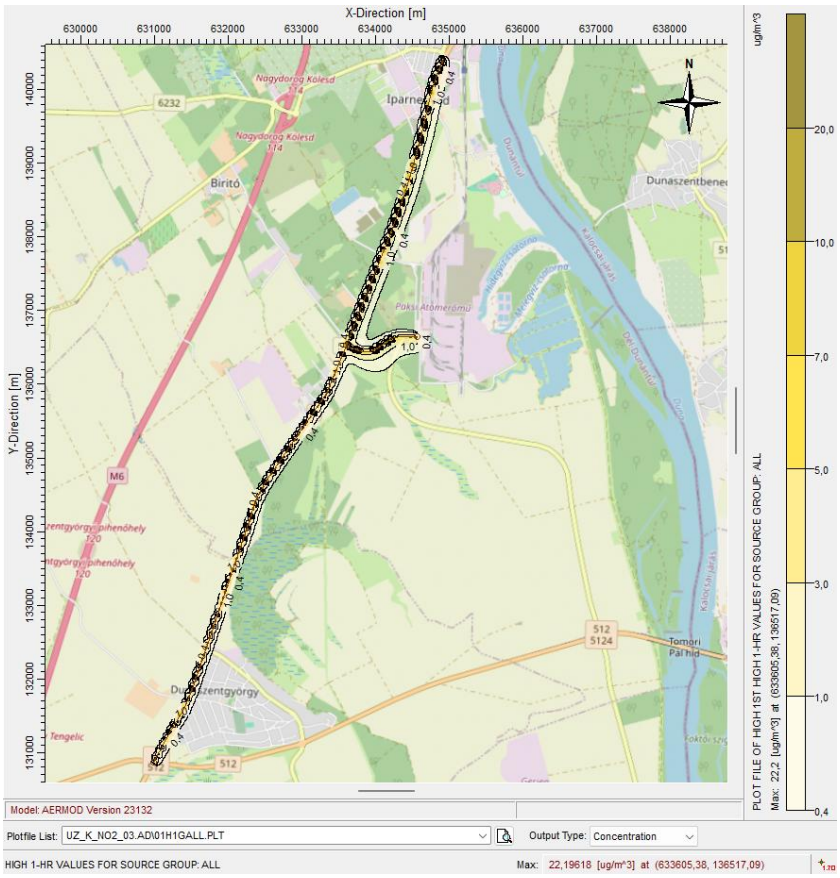


Figure 4.1.6-3. Hourly nitrogen-dioxide (NO_2) concentrations calculated for traffic releases associated with the independent operation of the Paks NPP

The results of the studies on the joint operation of the Paks NPP and Paks II NPP during the SSLE period are summarized in *Table 4.1.6-4.*, while the calculated hourly concentration of nitrogen-dioxide is shown in *Figure 4.1.6-4*.

Table 4.1.6-4. Summary of the effects of the joint operation of the Paks NPP and Paks II NPP during the SSLE period on air quality

	Air pollutant	
	Nitrogen-dioxide (NO_2)	**Carbon-monoxide (CO)**
Max. concentration [µg/m³]	173.0	7.9
Exceeding the limit value	On the operational area.	None.
Exceeding load capacity	On the operational area.	None.
Impact area	Areas within a 700-metre radius of the releases, including both on-site and off-site areas.	Within a 400-metre radius of the releases: on the site.
Description of impacts	The effects of diesel generator trial operation on nitrogen-dioxide levels will be long-term but periodic. The magnitude of the impact will reach the threshold level. However, these effects will occur only periodically and will affect only a relatively small portion of the affected area.	The effects on carbon-monoxide releases are neutral.

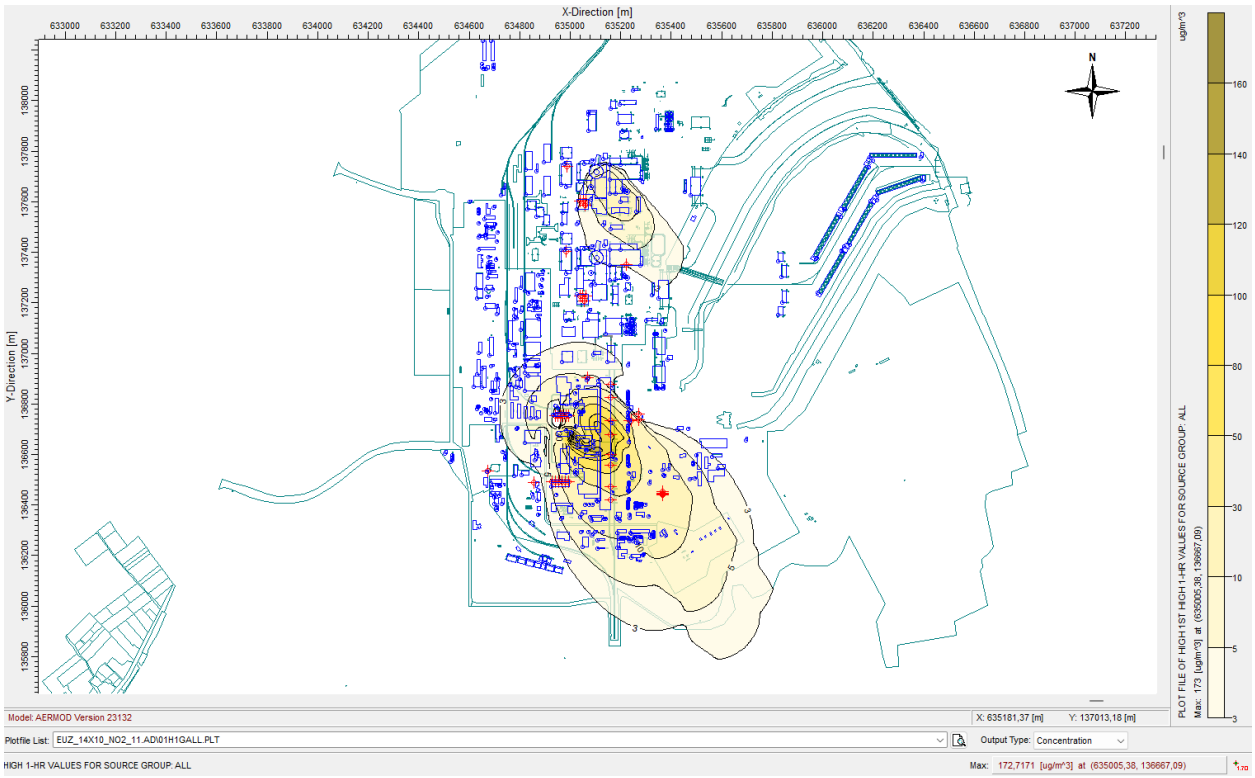


Figure 4.1.6-4. Hourly nitrogen-dioxide (NO_2) concentrations calculated for the joint operation of the Paks NPP and Paks II NPP during the SSLE period (during the trial operation of the diesel generators)

The results of the studies on the traffic impacts associated with the joint operation of the Paks NPP and Paks II NPP during the SSLE period are summarized in *Table 4.1.6-5.*, while the calculated hourly concentrations of nitrogen-dioxide are shown in *Figure 4.1.6-5*.

Table 4.1.6-5. Summary of the impact of traffic associated with the joint operation of the Paks NPP and Paks II NPP during the SSLE period on air quality

	Air pollutant	
	Nitrogen-dioxide (NO_2)	**Carbon-monoxide (CO)**
Max. concentration [µg/m³]	22.5	61.4
Exceeding the limit value	None.	None.
Exceeding load capacity	None.	None.
Impact area	Along the southern access road to the Paks NPP, within 30 metres of the edge of the roadway. Along the section of Main Road No. 6 between the southern access road to the Paks NPP and the Paks-Kölesdi Road intersection, within 20 metres of the edge of the roadway.	Along the southern access road to the Paks NPP, within 10 metres of the edge of the roadway.
Description of impacts	The impacts will be neutral.	The impacts will be neutral.

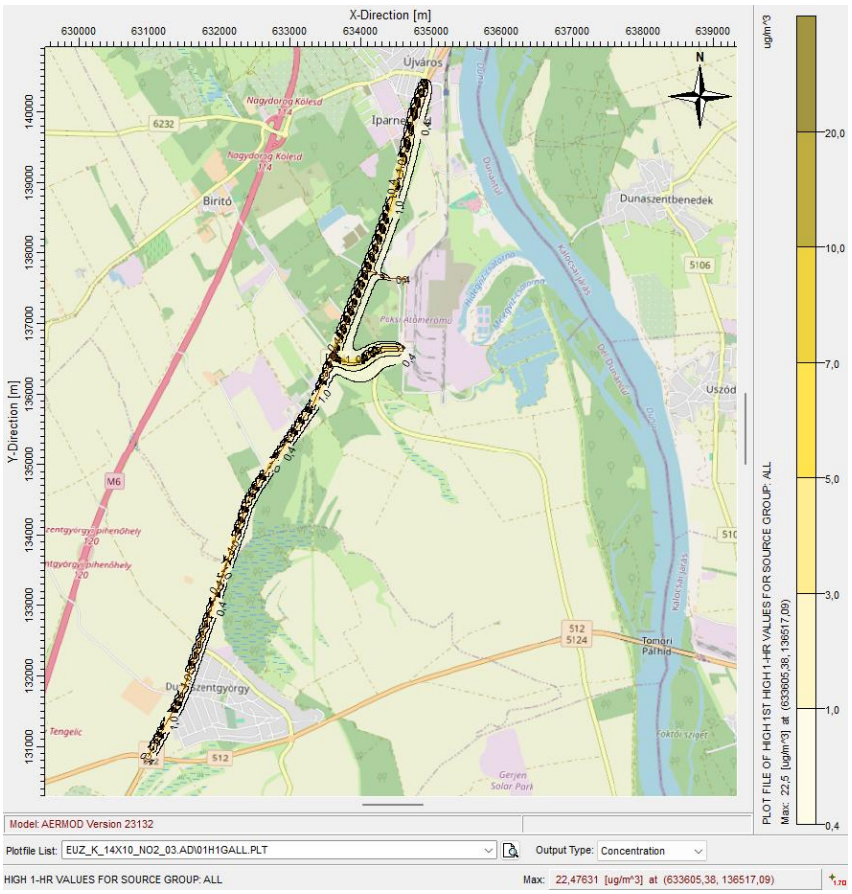


Figure 4.1.6-5. Hourly nitrogen-dioxide (NO_2) concentrations calculated for releases from transportation related to the joint operation of the Paks NPP and Paks II NPP

The results of the analyses conducted for the emergency event scenarios considered in connection with the operation of the Paks NPP are summarized in *Table 4.1.6-6.*, while the calculated hourly concentrations of nitrogen-dioxide are shown in *Figure 4.1.6-6*.

Table 4.1.6-6. Summary of the effects of the investigated emergency event on air quality in connection with the operation of the Paks NPP

	Air pollutant	
	Nitrogen-dioxide (NO_2)	**Carbon-monoxide (CO)**
Max. concentration [µg/m^3]	338.0	17.2
Exceeding the limit value	On the operational area.	None.
Exceeding load capacity	On the operational area.	None.
Impact area	Areas within a 1,600-metre radius of the release source, including both on-site and off-site areas.	Within a 550-metre radius of the source of releases within the site.
Description of impacts	The effects of a malfunction in diesel generators occur during the duration of the event. The intensity of these impacts reaches the threshold level within the impact area.	The impacts will be neutral in terms of carbon monoxide exposure.

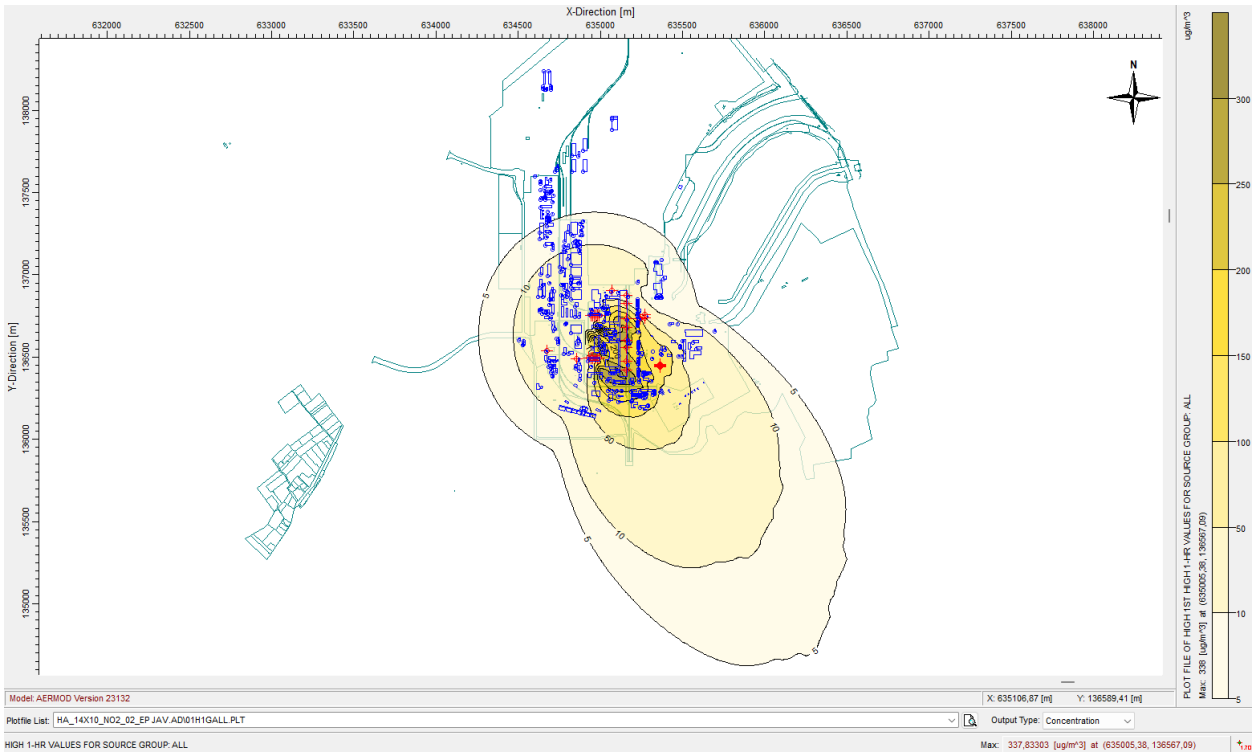


Figure 4.1.6-6. Hourly nitrogen-dioxide (NO_2) concentrations calculated for the emergency event scenario (operation of diesel generators) examined in connection with the operation of the Paks NPP

4.1.7. Potential transboundary environmental impacts

The impact areas calculated for releases of non-radioactive air pollutants apply to the NPP site and its immediate vicinity. With regard to transportation related to the NPP, environmental impacts occur along the access roads to the plant and in the immediate vicinity of Main Road No. 6 between Paks and Dunaszentgyörgy.

Based on the results of the investigation and the distance of the affected areas from the national border, it can be concluded that no transboundary environmental impacts are expected for the air pollutants examined.

4.2. Examination of climatic conditions, exposure to climate change, and climate resilience assessment

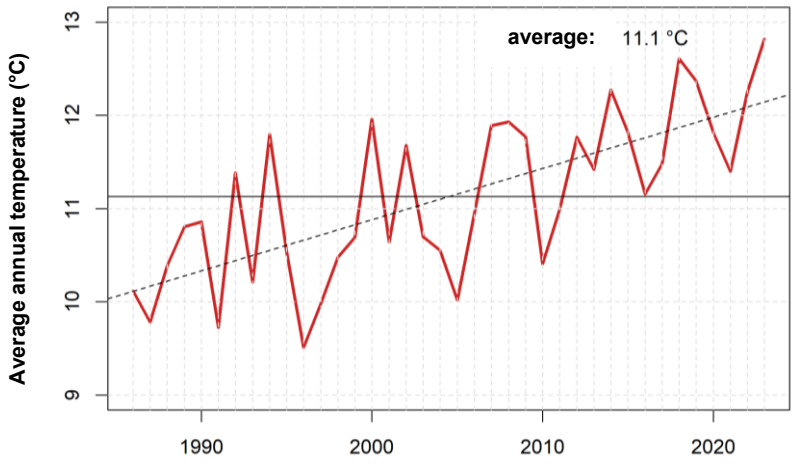
4.2.1. Meteorological characteristics in the vicinity of the site

Weather conditions have a fundamental impact on the operation of industrial facilities. Furthermore, with regard to the Paks NPP, air temperature is the primary factor determining the water temperature of the Danube. Therefore, the analysis of key meteorological variables is crucial. The climatological and meteorological characteristics of the Paks NPP site have been summarized by updating the results for the period 1981-2010, which were previously compiled by the Hungarian Meteorological Service (the predecessor of HungaroMet Zrt.) for earlier studies.

Temperature, precipitation

For the period 1981-2010, the average annual temperature at the Paks meteorological station was 10.7°C, while for the period 1991-2020, based on more recent measurement data, it rose to 11.1°C. *Figure 4.2.1-1* shows the trend of annual mean temperatures for the period 1986-2023. The long-term average air temperature for the 1986-2023 period was 11.1°C, matching the 30-year climate average. A clear increase can be observed in the trend of annual mean temperatures, with the rate of temperature rise amounting to 0.58°C every 10 years. During the

1986-2023 period, the highest daily maximum temperature was recorded on July 20, 2007 (40.6°C), and the lowest on January 13, 1987 (-13°C).



Note: The numeric value shown in the figure represents the average for the period 1986–2023. The dashed line represents the fitted trend

Figure 4.2.1-1. Average annual temperature data (°C) for the Paks meteorological station for the period 1986-2023

A heatwave day is defined as a day when the mean daily temperature exceeds 25°C. The average annual number of heatwave days over the entire 1986-2023 period was 12.5 days at the Paks station, with the highest value recorded in 2021 (29 days), though 2015 also saw high values with 28 days. The number of heatwave days shows a significant increase.

Hot days are defined as days when the daily maximum temperature exceeds 35°C. Based on measurements, the average annual number of hot days for the entire period from 1986 to 2023 was 5.9, with the highest value occurring in 2015 (19 days). The time series shows an increase, but the level of significance is low, so the increase is not clear.

During the 1981-2010 period, the average annual precipitation was 599 mm, while during the 1991-2020 period it was 596 mm. Based on the annual precipitation totals for the 1986-2023 period, no trend can be observed in the data. The average annual number of days with heavy precipitation (>30 mm) ranged from 0 to 5 days within the NPP site, based on station-measured data, averaging 1.66 days per year. No trend can be identified in the data series. The annual average number of days with extremely high precipitation (>44 mm) was 0.36 at the Paks station between 1986 and 2023, with the highest number of such days occurring in 2010 (3 days). No trend can be identified in the data series here either.

Wind conditions, atmospheric stability

For the period 1996-2023, the relative frequency of wind directions was similar to that of the 1981-2010 period; north-westerly (11.1%) and north, north-westerly winds (10.8%) were the most common, followed by the north (8.7%) and south (8.6%) winds.

The average annual wind speed was 1.7 m/s during the 1991-2020 period, while it was 1.8 m/s during the 1986-2023 period. During the 1986-2023 period, the highest recorded wind gust occurred on February 27, 1990, reaching 27.5 m/s. Days with extreme wind gusts (wind speed >85 km/h) occurred a total of ten times during the entire 1986-2023 period, based on measurements from the Paks NPP.

To perform atmospheric dispersion calculations, it is necessary to specify not only wind speed and wind direction but also stability conditions. The most important parameter characterizing atmospheric stability is the vertical structure of air temperature. Vertical stratification is determined by the ratio of solar radiation to ground radiation, as well as by wind speed. Atmospheric conditions are typically classified into categories based on stability. In international practice, the Pasquil classification system has become widely used for environmental impact calculations for

NPPs, and it is also recommended by the International Atomic Energy Agency (IAEA). Depending on atmospheric conditions, the categorization ranges from “A” to “F,” where category “A” indicates highly unstable atmospheric conditions, “B” moderately unstable, “C” slightly unstable, “D” neutral, “E” slightly stable, and “F” stable conditions.

During the 2013-2022 period, the most common category was “C” (34.2%), while the second most common category was “D” (24.2%). This was followed by category “B” (20.6%), then “A” (11.7%) and “E” (7.3%), and finally category “F” (2%).

4.2.2. Climate change projections

In the context of climate change, projections about the future can only be made if we make certain assumptions regarding expected social, economic, and political decisions. The results of two such scenarios, known as RCPs (Representative Concentration Pathways) – RCP4.5 and RCP8.5 – were used in the analyses. RCP8.5 is the most pessimistic scenario, assuming high greenhouse gas emission without any effective climate policy, while RCP4.5 is a more optimistic scenario in which emission reduction efforts are successful to a given level. 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 RCP8.5 projects an increase of 3.5-5.3°C compared to the end of the 20th century. The projected change in annual precipitation by the end of the century is expected to range from -5% to 16% (RCP4.5) and from 0% to 24% (RCP8.5).

Source of meteorological data

The meteorological data used to investigate the effects of climate change are not based on measurements, but on calculations derived from state-of-the-art climate models. The ovierview of climate change projections uses an ensemble (i.e. probabilistic, using multiple model results) approach. An average (ensemble-mean) can also be derived from the ensemble data, which can be interpreted as the most likely scenario based on the models used and presents the most probable future outlook. It should be emphasized here that this assessment is based on current knowledge. Therefore, it does not provide certainty, but rather indicates what currently appears most likely based on the projections used. Future social, economic, and political changes and decisions will fundamentally influence the future climate, which, understandably, cannot be accurately predicted.

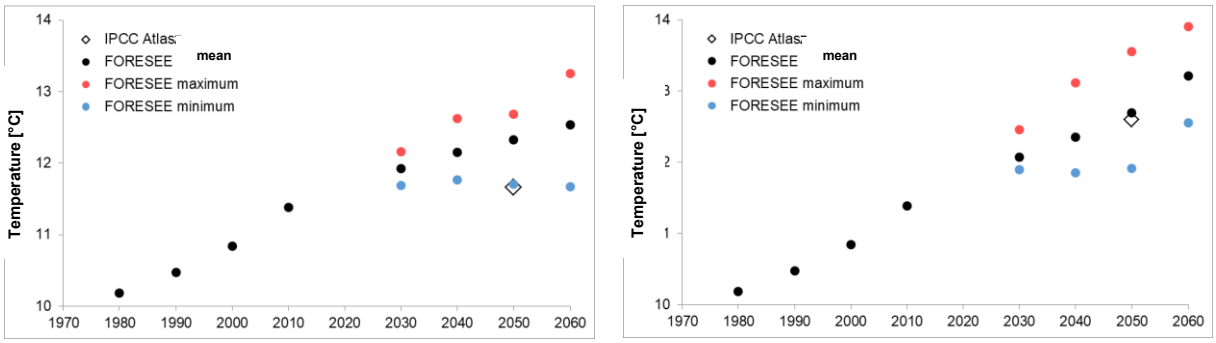
The variables under examined were defined for four past periods (1971-1990, 1981-2000, 1991-2010, 2001-2020) and four future periods (2021-2040, 2031-2050, 2041-2060, 2051-2070). Based on the available data, the most likely future scenario is based on the average of the 14 models in the FORESEE database, and the derived trends were also estimated based on this. The trends were determined in two ways. A linear trend function was fitted to the longest possible period (1971-2070) and to a shorter period covering the recent past and the near future (2001-2060). The trend estimation for these two periods of different lengths was justified by the fact that the magnitude of change depends significantly on the selected time period. The results of the so-called IPCC Atlas were used as additional information, and the relevant projections were included as a supplement to the FORESEE results.

The projections were discussed separately, distinguishing between the RCP4.5 (more optimistic) and RCP8.5 (pessimistic) scenarios. It is important to note that some research findings suggest that current projections for Europe, based on regional climate models, are overly optimistic and may underestimate the expected changes, at least in terms of temperature rise and the frequency of summer heatwaves. For this reason, in addition to examining the expected ensemble average based on a large number of models, it is also worth considering uncertainty, particularly the range of values that defines the upper limits.

Annual mean near-surface air temperature

Based on FORESEE, it can be concluded that the annual near-surface air temperature will continue to rise in the future compared to the current value of ~11.4°C, which was recorded between 2001 and 2020. Taking the entire period into account, warming is expected between

1971 and 2070, with a decadal rate of ~0.3°C based on the more optimistic scenario and ~0.4°C based on the pessimistic scenario (*Figure 4.2.2-1.*). If the analysis covers only the period between 2001 and 2060, the expected rate of warming is more moderate: ~0.2°C per decade under the more optimistic scenario and ~0.3°C per decade under the pessimistic scenario. For the period between 2041 and 2060, the more optimistic scenario projects an annual average near-surface air temperature of ~12.3°C, while the pessimistic scenario projects ~12.7°C. The IPCC Atlas projects a smaller temperature increase than the FORESEE mean for the period between 2041 and 2060; according to the more optimistic scenario, an annual average near-surface air temperature of ~11.7°C is expected, while the pessimistic scenario projects ~12.6°C.



Note: The symbols in the figure represent 20-year averages. Therefore, they do not refer to individual years but illustrate trends. The mean, minimum, and maximum values from the FORESEE database are shown in black, blue, and red, respectively. The black diamond shows the IPCC Atlas's average projection for the period between 2041 and 2060.

Figure 4.2.2-1. Projected annual near-surface air temperature for the area surrounding the Paks NPP based on (a) the optimistic scenario and (b) the pessimistic scenario

Seasonal mean near-surface air temperature

Based on the FORESEE database, the mean near-surface air temperatures will rise in the future compared to current levels, both during the winter (December, January, and February) and the summer (June, July, and August). The results for seasonal near-surface air temperatures are very similar to those for annual values.

Based on the FORESEE ensemble mean, the mean near-surface air temperature during the winter months between 1971 and 2070 is projected to increase from the current value of ~1.1°C, with a projected rate of ~0.3°C per decade under the more optimistic scenario and ~0.4°C per decade under the pessimistic scenario. Considering the periods between 2001 and 2060, both the optimistic and pessimistic scenarios project a warming rate of ~0.4°C per decade. According to the IPCC Atlas, a smaller increase is expected compared to FORESEE; the more optimistic scenario forecasts an average winter near-surface air temperature of ~1.5°C, while the pessimistic scenario forecasts ~2.3°C.

Based on the FORESEE ensemble mean, between 1971 and 2070, the mean near-surface temperature during the summer is expected to increase by approximately 0.4°C per decade compared to the current value of ~21.3°C, under both the optimistic and pessimistic scenarios. If only the period between 2001 and 2060 is considered, the expected rate of warming is ~0.3°C per decade under both the more optimistic and pessimistic scenarios. Compared to FORESEE, the IPCC Atlas projects a smaller increase for the period between 2041 and 2060 under the more optimistic scenario; i.e., it predicts a value of ~21.7°C, while the pessimistic scenario forecasts a summer average near-surface temperature of ~22.6°C.

Number of spring days (freezing) with a minimum temperature below 0°C

The projected decrease in the number of spring days with freezing temperatures is consistent with the previously reported results indicating a warming trend. The expected average decrease per decade, based on the FORESEE mean and considering the entire period from 1971 to 2070, is approximately 1 day under both the more optimistic and pessimistic scenarios. Compared to

the current annual average of ~16.6 days, the expected number of spring frost days for the period between 2041 and 2060 is ~14.4 days/year and ~12.6 days/year, respectively. Based on an analysis of the periods between 2001 and 2060, a decrease is expected at the 0.1 significance level, amounting to ~0.5 days under the more optimistic scenario and ~1 day under the pessimistic scenario. The IPCC Atlas projects a smaller decrease compared to the FORESEE average for the period between 2041 and 2060, estimating ~17.2 days/year under the more optimistic scenario and ~15 days/year under the pessimistic scenario for annual spring frost days.

Number of days (hot days) with maximum temperatures above 35°C

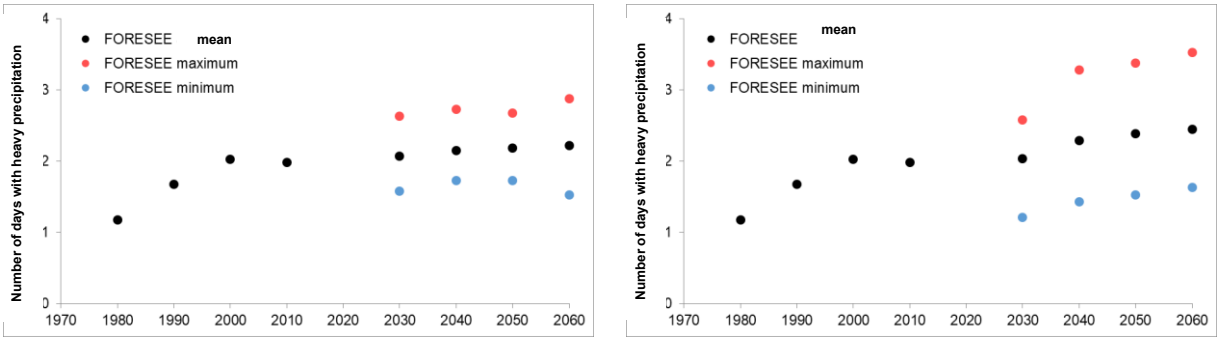
According to FORESEE, when examining the periods between 1971 and 2070, the number of days with maximum temperatures above 35°C is projected to increase by approximately 1.7 days per decade under the more optimistic scenario and by approximately 1.8 days per decade under the pessimistic scenario. Based on the shorter period between 2001 and 2060, compared to the current value of ~6.2 days/year, the number of days with maximum temperatures above 35°C is expected to increase by ~1.9 days/decade under both the optimistic and pessimistic scenarios, meaning that for the years between 2041 and 2060, a figure of around 13.7-13.9 days is likely. The IPCC Atlas's more optimistic scenario projects a significantly smaller increase compared to the FORESEE mean for the period between 2041 and 2060, only ~8.8 days per year, while the pessimistic scenario forecasts a value similar to the FORESEE mean's pessimistic scenario; i.e., ~14 days per year with maximum temperatures above 35°C.

Number of heatwave days (daily mean temperature above 25°C)

Based on the FORESEE mean, the expected number of heatwave days per year is projected to increase by approximately 3.4 days and approximately 4 days per decade, under both the more optimistic and the pessimistic scenarios, regardless of whether the period under consideration is 1971-2070 or 2001-2060. Thus, from the current value of ~13 days/year, the number of heatwave days is expected to increase to ~26.5 days per year for the period between 2041 and 2060 under the more optimistic scenario, while it will increase to ~29.3 days under the pessimistic scenario. (The variable for the number of heatwave days is not available in the IPCC Atlas).

Number of days with heavy precipitation

The FORESEE mean indicates an upward trend in the number of days with heavy precipitation – that is, the number of days on which total precipitation exceeded 30 mm – per decade, according to both the optimistic and pessimistic scenarios, based on the periods between 1971 and 2070 and between 2001 and 2060. However, the rate of increase is only around ~0.1 days per decade (*Figure 4.2.2-2*). The current number of days with heavy precipitation is around ~2 days per year, which is likely to remain the same during the period between 2041 and 2060.



(a) (b)

Note: The symbols in the figure represent 20-year averages. Therefore, they do not refer to individual years but rather illustrate trends. The mean, minimum, and maximum values from the FORESEE database are shown in black, blue, and red, respectively.

Figure 4.2.2-2. Number of days with heavy precipitation – that is, days on which total precipitation exceeds 30 mm – in the Paks region under (a) the more optimistic and (b) the pessimistic scenarios

Number of days with extremely high precipitation

The FORESEE mean predicts an upward trend in the number of days with extremely heavy precipitation – that is, the number of days on which total precipitation exceeds 44 mm – for each decade, based on the periods between 1971 and 2070 and between 2001 and 2060. The current annual number of days with extremely high precipitation is around ~0.36 days, which is likely to increase between 2041 and 2060 as well, though the rate of increase is only around ~0.1 days per decade. (No similar analysis is available in the IPCC Atlas.)

Number of days with wind gusts exceeding 85 km/h

Days characterized by very strong wind gusts – that is, the number of days on which the strongest wind gust exceeds 85 km/h – show only very slight changes per decade in the averages of the non-bias-corrected Euro-CORDEX models under both the optimistic and pessimistic scenarios, based on averages for the periods between 1991 and 2060. The uncertainty of the projection is illustrated by the fact that, on a 20-year average, the models typically estimate the number of days affected by this phenomenon to be between 0 and 1 for the period between 1991 and 2060.

Future trends in the Danube's discharge and water temperature

The time series of discharge forecasts extending to 2060 do not show any radical changes in any of the climate scenarios compared to the 2000-2020 period. The discharge values from individual model projections cover the entire range of historical discharge values, albeit with slightly different seasonal timing, while extreme discharges occur in both directions. The FORESEE database predicts a slight increase in total precipitation across the entire Danube river basin upstream of Paks for nearly all climate GCM-RCM model chains. Accordingly, following the declining discharge trends of the 2000-2020 period, a roughly immediate trend reversal and a slow increase in discharges are expected in both scenarios, accompanied by increased variability.

The distribution of future discharges differs from that of the present under both climate scenarios. Under the RCP4.5 optimistic climate scenario, mean discharges remain unchanged, while peak discharges increase slightly. More significant changes are expected for low water conditions, with a substantial decrease in daily return period discharges of 1% and 0.1%. There is a small probability that daily return period discharges below 1% could fall below 500 m^3/s. However, a significant decrease is highly likely for discharges below the median.

Under the RCP8.5 pessimistic scenario, the increase in high water discharge may be more pronounced. Medium water discharge will increase slightly, with discharge levels similar to current ones occurring within the 20% probability range. Below this threshold, water discharge will decrease to an extent similar to that observed in the RCP4.5 scenario.

During the forecast period, the current record low water level (LWL = -97 cm) is expected to be broken, but the extent of this is uncertain due to the methodology of the projection. Exceeding the current highest water level (HWL = +891 cm) is not expected in the optimistic scenario, but it may occur in the RCP8.5 scenario.

Under the RCP4.5 optimistic climate scenario, the temporal trend in annual maximum discharges is not significant for any of the climate model chains, and a decrease in minimum discharges is unlikely. The direction of the annual median change varies, but the trend is not steep. In the RCP8.5 pessimistic scenario, none of the discharge indicators are stable; all show trends toward either stability or increase. This indicates a significant increase in hydrological variability alongside slightly rising discharge levels.

Seasonal variations in discharge are quite diverse. Currently, annual peaks typically occur from April through September or during the second half of winter. The period of lowest discharge extends from the second half of August through March. This pattern will essentially remain the same in the future, but there will be no period during which extreme low-water or high-water events can be ruled out with certainty.

Monthly hydrological extremes will change significantly in the future. Spring low flows will decrease substantially under both climate scenarios, while high discharges will typically increase in the second half of the year. The decrease in median values is also likely to be significant in both summer and fall.

The rise in the Danube's water temperature will continue, but the rate of increase will drop to nearly one-tenth of its current level. According to model simulations, the temperature increase during the summer will be only 0.15-0.23°C per decade by 2060 under both climate scenarios examined.

The water temperature values associated with the given probabilities of below-average conditions will increase in all cases during the 2021-2060 period, although not significantly for the lower probabilities. In terms of seasonality, it can be observed that summer maximums are shifting somewhat earlier in the season. Future monthly maximums show a sharp increase during the autumn cooling period.

4.2.3. The impacts of the NPP's continued operation on meteorological and climatic conditions

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

- The presence of the site itself, and the so-called urban heat island effects caused by built-up areas.
- The thermal load of the power plant:
  - heat release to the ambient air resulting from the higher water temperature of the Danube, as an indirect effect of heat discharge into the Danube via the freshwater-cooled cooling system,
  - direct heat releases into the atmospheric environment resulting from the operation of the planned peak cooling system (vapour releases from mechanical draft wet cooling cells).

4.2.3.1. The urban impact resulting from built-up areas

The Paks NPP and its associated facilities significantly altered the characteristics of the landscape at the time of their construction. Former agricultural land and biologically active surfaces were built on, which significantly affected, for example, the area's albedo, evaporation conditions, and biological activity. Activities carried out on the site (e.g., heat releases from buildings, stormwater drainage, etc.) and the operation of the facility emerged as additional influencing factors.

As a result of the difference in the 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 a few tenths of a degree Celsius on an annual average; the effect is more pronounced during the colder winter months. The effects are observed in the power plant area and its immediate surroundings (parking areas, roads).

Surface roughness and heat balance conditions that differ from those of the surrounding area can also lead to changes in local airflow patterns and air movement, which in turn cause local variations in evaporation and air humidity conditions.

Given that the Paks NPP has been in operation for decades, it can be stated that the SSLE will not trigger any previously unobserved effects; in other words, no changes to the condition or functions of the site are to be expected. Due to the built-up nature of the site – and given the nature of the infrastructure – the continued independent operation of the Paks NPP will have no significant impact on changes in the site's meteorological and climatic conditions. This will not change as climate change progresses. However, due to global warming, the urban heat island effect – which already exists – is expected to intensify.

During the operation of the Paks NPP with its extended service life, significant new construction will be carried out along the route of the alternative warm-water channel, as well as the associated cooling cells and their related equipment, structures, and other facilities. This facility will be constructed largely on land previously used as forest and fishponds, thereby increasing the size of the power plant area previously affected by urban development.

With the construction of the Paks II NPP, the area of undeveloped, vegetated land at the Paks site will continue to decrease, and as a result, the spatial extent of the urban impact is expected

to be limited to the Paks II NPP site and to increase slightly, even when climate change is not taken into account.

It should be noted here that the reduction in the soil-vegetation system's evapotranspiration capacity is also an obvious consequence of increased urbanization, which makes the environment around built-up areas drier. In this context, however, the evaporation-based cooling systems planned for both NPPs can also be interpreted as partially compensating for the evaporation deficit resulting from urbanization during the most critical, persistently hot summer period.

4.2.3.2. Impacts resulting from thermal loading of the Danube

Heat releases from the cooling systems of fresh-water-cooled thermal power plants can cause local changes in certain climatic parameters. According to the results of targeted investigations of mesoclimatic effects conducted as part of the site characterization program associated with the first service life extension, these effects are limited to the immediate vicinity of the NPP and, due to the thermal load on the Danube, the narrower river valley. This is further supported by the fact that the meteorological measurements taken continuously since the NPP was built have not revealed any significant deviations in the measured parameters compared to the trends observed nationwide.

As part of the environmental impact investigation for the first service life extension of the NPP, the potential meteorological effects of the thermal load on the Danube were examined using two spatial scales and two methods:

- Local microclimatic impacts that may occur over the water and directly along the shore. The presence of these impacts was inferred from air temperature and humidity. The investigation examined the magnitude and significance of these impacts.
- Environmental mesoclimatic impacts are those (potential) climatic impacts that may occur at distances of several kilometres from the point where the heat surplus enters the Danube and persists, even beyond the linear source. It was assumed that – if any impacts occur at all – they would depend heavily on weather conditions, large-scale wind direction, stability, etc. These impacts were also examined using modelling.

The measurement program revealed that the thermal load from the NPP is detectable only immediately adjacent to the warm-water channel. In most cases, the difference between the temperature readings taken above and below the warm-water channel remained below 1°C. At the measuring station set up 200 m downstream of the warm-water channel, the impact of the thermal load was no longer detectable in the monthly and annual temperature data sets.

Based on the measurements and modelling conducted, it was determined that the thermal load caused by the heated cooling-water discharged from the NPP into the Danube – although detectable – does not represent a change in the atmospheric environment significant enough to warrant intervention. The reported discrepancies:

- on a climatological average, even on the right bank of the river, near the confluence of the warm-water channel, these differences are smaller than the natural climatic variations that frequently occur between two lowland stations within the country,
- the largest observed and modelled impacts are smaller than the daily temperature range typical of normal weather variability on the river's right bank for most of the year, but they are certainly smaller than the most extreme weather changes that occur from one day to the next,
- no warm water impact could be detected through measurements taken on the left bank of the river; furthermore, an analysis based on weather conditions confirmed that the observed impact could be explained not by the cross-sectional impact of warm water, but by other, independent microclimatic factors,
- the modelled warm-water impact, which can be observed even several kilometres from the river under certain weather conditions, is at least partly attributable to the idealized, flat surface; accounting for the protective effect of natural vegetation and its ability to create

alternative microclimates, this impact would certainly be less pronounced than on the left bank, and indeed on the right bank, even at the measuring site located farther from the confluence, where it exceeded the impact in question.

These circumstances suggest that, in order to survive, the surrounding ecosystems have had to adapt to much greater variations – both in terms of climate and weather – than the warm-water impact demonstrated by direct measurements and modelling. At the same time, the findings from measurements and the greater differences observed compared to an idealized surface strongly suggest that, regardless of the presence of the NPP, it is essential to protect the natural vegetation cover in the region, which filters and reduces climate-altering impacts.

The two studies, conducted using independent methodologies, made it possible to clearly determine the magnitude of the thermal load caused by the discharge of warm-water resulting from the operation of the NPP. The resulting impact is less than that of three natural factors (regional climate differences, daily weather variations, and certain competing microclimatic differences) to which ecosystems have been able to adapt thus far. Based on the investigation results, no further studies were warranted regarding the thermal load caused by warm water.

With regard to the independent operation of the Paks NPP, based on the available information, no changes in mesoclimatic characteristics resulting from the thermal load on the Danube are anticipated during the plant's continued operation.

Once the Paks II NPP becomes operational, the thermal load on the Danube will nearly double compared to current levels. This will obviously intensify the impact, but it will not reach a level that would call the above findings into question.

The climatic impacts resulting from the thermal load on the Danube caused by the discharge of warmed cooling-water from the two NPPs are expected to remain detectable locally at the power plant site and in the immediate vicinity of the warm-water channels. However, no mesoclimatic changes can be expected as a result, even despite the return of twice the volume of warmed cooling-water. It is assumed that, as is currently the case, the degree of detectability will remain only minor in the future.

4.2.3.3. Impacts resulting from the operation of the planned peak cooling system

For the period of the SSLE of the Paks NPP, MVM Paksi Atomerőmű Zrt. plans to construct the alternative warm-water channel section described in *Chapter 2.2.2.1.* and the connected peak cooling system. The purpose of the cooling system is to reduce the temperature of the warmed cooling-water before it is discharged, ensuring that the upper water temperature limit of 30°C – as required for the Danube cross-section located 500 metres downstream of the intake point – can be maintained even when Danube water temperatures are high, while sustaining the power plant's output, taking into account the operation of the Paks II NPP.

Like the Paks NPP, the Paks II NPP will operate with fresh-water cooling system; plans call for the installation of a similar peak cooling system along the new warm-water channel to be constructed for Paks II NPP, designed to provide secondary cooling for the warmed cooling-water.

However, the cooling cell arrays of the peak cooling systems are not in continuous operation at any of the NPPs; they are brought online only during critical periods (when Danube water temperatures are high) and in a phased manner. Their total operating time is expected to be limited to only short periods on an annual basis, during summer heatwaves. The peak cooling systems to be installed will emit large amounts of water vapour during operation, which is expected to affect the microclimate. Given this vapour release, it is likely that air humidity levels in the vicinity of the NPPs will be affected from time to time.

As part of the environmental impact investigation, the amount of vapour emitted by the peak cooling systems of the two NPPs was determined, along with its effect on changes in the relative humidity of the atmospheric environment surrounding the peak cooling system. Based on the studies, it can be concluded that the additional vapour volume exiting the cooling cells will disperse at an altitude of 100-400 m above ground level, where it is continuously transported away by air entering and leaving the spatial domain from the prevailing wind direction. Due to the

mixing of the air, this increase in vapour content practically disappears entirely within a few kilometres of the peak cooling system.

The amount of water evaporating into the air is approximately 1.5% of the total cooling-water flow at NPPs during full-load operational condition, while this figure is 0.5% during partial-load operation, which occurs 3-4 days a year.

Based on the results, the expected relative humidity in the space above the cooling units will remain below 85% even under maximum load on the two peak cooling systems and under the most unfavourable wind conditions (wind speed <0.5 m/s). Thus, even if moisture is locally visible in the spatial domain of a few tens of metres above the cooling cells, the visible moisture from the extra moisture release will quickly evaporate in the large air volume and will not form a significant cloud. It can also be concluded that the frequency of operational conditions associated with the greatest increase in humidity is negligibly small.

At higher wind speeds, more fresh air enters the tested spatial domain, while the amount of moisture emitted by the cells remains the same. Thus, the larger volume of air exiting the space will result in a smaller increase in relative humidity compared to the case with a wind speed of 0.5 m/s. A smaller increase in relative humidity can also be expected in the more common operational conditions that can be managed with partial loading of the peak cooling systems.

Given that peak cooling systems operate during prolonged periods of hot summer weather, when air humidity is generally low, the effect of moisture release can be considered positive, as it compensates for part of the evaporation deficit caused by urbanization during the most critical periods of prolonged hot summer weather. Its positive effect is primarily evident in nighttime and early morning dew formation, which provides moisture that plants can utilize.

4.2.4. Climate resilience assessment

4.2.4.1. Assessment methodology, approach used

As a general principle, adaptation to a climate that is becoming more extreme due to climate change – that is, a conscious adjustment to the climate of the future – must be a guiding factor in the planning and implementation of various projects. Of all types of projects, those aimed at infrastructure development are perhaps the most vulnerable to future climate conditions – primarily due to their planned service life.

At the European Union level, it is now a requirement that a so-called climate change resilience assessment be conducted for all infrastructure projects planned for a period of at least five years. The assessment facilitates the identification of infrastructure developments that involve significant greenhouse gas (GHG) releases or are particularly vulnerable to future climate conditions, thereby providing project planners with the opportunity to incorporate supplementary measures into their projects – by assessing the expected impacts of climate change and the associated risks – that are essential for ensuring the resulting infrastructure can operate cost-effectively in the long term and fulfil its intended purpose.

The assessment of the Paks NPP's exposure to and sensitivity to climate change – in connection with the SSLE – was carried out in accordance with the Climate Resilience Guideline (February 2022), commissioned and published by the Prime Minister's Office, following the standard climate change resilience assessment methodology and steps outlined therein. The assessment consists of two parts – partially interrelated yet clearly distinguishable:

1. Climate neutrality sub-assessment: an assessment of the expected change in GHG releases resulting from the project
2. Climate Adaptation sub-assessment: assessing the project's adaptation to climate change.

The aim of the studies is to identify high-risk infrastructure projects – that is, those that result in significant GHG releases or are particularly vulnerable to climate impacts – and to encourage the integration of climate protection and adaptation considerations into their planning and implementation. The standard climate change resilience assessment consists of two interrelated

phases in each of its two sub-assessments: a screening phase and a detailed analysis phase. The latter is required only if the results of the screening phase indicate that it is warranted.

According to the guidelines, infrastructure refers to network infrastructures essential to the functioning of the economy and society, including, among other things, energy infrastructure, and within that, power plants. Given that the planned duration of the SSLE of the Paks NPP, which forms part of the domestic electricity infrastructure, is 20 years, a climate resilience assessment (the standard version) was conducted in accordance with the guideline.

The purpose of the climate neutrality sub-assessment was to determine, whether the expected change in annual GHG releases resulting from the planned development is consistent with the release reduction targets set by the European Union and, as part of it, by Hungary. Because of the electricity generation activities at the Paks NPP – thanks to the nuclear technology used – no GHG releases are released into the atmosphere. The NPP does not use conventional combustion equipment for electricity generation, nor does it use fuels whose combustion results in the release of large amounts of flue gas and, consequently, GHG releases into the atmosphere. From this perspective, the SSLE will not result in any change in GHG releases compared to the current situation.

However, in connection with the operation of the NPP, there are several pieces of equipment at the plant site – primarily intended for safety purposes (e.g., diesel generators powering emergency power sources) – whose operation results in GHG releases. However, the annual operating time of these facilities is low, limited to test runs for inspection purposes. In this regard, there will be no significant change during the planned service life extension period – even taking into account the planned installation of new emergency replacement diesel generators for Units 1 and 2 – meaning that no significant change (increase) in GHG releases is expected from these sources compared to current levels.

Road transport (passenger and freight) can be identified as another significant source of GHG releases associated with the operation of the NPP. With regard to road transport required for the operation of the NPP, no significant increase in traffic is expected during the SSLE period beginning in 2032, given that no substantial increase in passenger and freight transport needs for the NPP is anticipated.

The climate neutrality sub-assessment was conducted with the above factors in mind, taking into account, on the one hand, the current operation of point sources of air pollution specified in the NPP's valid environmental permit and its amendments, and, on the other hand, the expected operation of the new emergency replacement diesel generators for Units 1 and 2, and on the other hand, based on the level of GHG releases attributable to current vehicle traffic associated with the plant's operation.

4.2.4.2. Partial climate neutrality assessment

The climate neutrality assessment consisted of the following two phases, which differed in their level of detail:

1. Screening phase: As part of the screening process, based on the project's sector classification and intended use, and using a preliminary list (Annex 1 of the Climate Resilience Guideline), it can be determined, whether the infrastructure investments to be implemented as part of the development are expected to result in a significant change in GHG releases.
2. Detailed climate neutrality analysis: This is required only if the results of the screening phase indicate that the GHG releases caused directly or indirectly by the implementation of the infrastructure project are likely to exceed 20,000 tons of CO_{2eq} per year.

The extension of the NPP's service life is not listed among the activities resulting in significant changes in GHG releases as defined in Annex 1 of the guideline. Therefore, a detailed climate neutrality assessment is not required under the guideline. Nevertheless, for verification purposes, activities associated with the operation of the NPP that result in GHG releases were identified, and the resulting releases were calculated.

Calculation of projected greenhouse gas releases

GHG releases associated with the operation of the Paks NPP result from the annual test runs of the existing emergency and other diesel-powered generators on the plant site, as well as the planned new emergency replacement diesel generators for Units 1 and 2 (point sources of air pollution), as well as from road passenger and freight traffic and the operation of internal combustion engine-powered road passenger and freight vehicles associated with the operation of the NPP.

The total annual GHG releases (CO_2) resulting from the operation of the NPP - calculated using a conservative approach – amount to: 128.28 t/year (point sources of air pollution) + 10,038.83 t/year (transportation) = 10,167.11 t/year. A similar value can be expected for the years of the NPP's additional 20-year SSLE. For CO_2, the global warming potential (GWP) is 1 (t_{CO2}/t_{GHG}), so the value expressed in carbon dioxide equivalent (CO_{2eq}) is: E_{total} (t CO_{2eq}) = $GWP_{CO2} \cdot E_{CO2}$ (t) = 10,167.11 t/year.

Therefore, neither the current operation of the NPP, nor its operation following the implementation of the SSLE project is expected to result in annual releases exceeding the threshold of 20,000 t CO_{2eq} specified in the guidelines.

Based on the above, the SSLE of the Paks NPP will not result in a significant change in GHG releases. Therefore, no further studies – such as a detailed climate neutrality analysis – are necessary.

Based on the above calculations, it is clear that GHG releases associated with the operation of the NPP are primarily attributable to road traffic. Therefore, the primary measures to reduce GHG releases should focus on modernizing the vehicle fleets used for passenger and freight transport, and increasing the proportion of electric vehicles in the fleet (e.g., expanding the electric charging network in parking lots associated with the NPP to encourage the use of electric vehicles).

The emergency diesel generators, which account for a small proportion of GHG releases, are activated in the event of an unexpected failure affecting the power plant's electricity supply, and are operated only for the necessary duration during trial operation conducted to verify their readiness. Given the specific requirements of the application, the required power output, the need to ensure reliable availability at all times, and the availability of fuel, diesel generators represent the best solution for this purpose. If MVM Paksi Atomerőmű Zrt. decides to replace the diesel generators in the future, low specific air pollutant and GHG releases will be taken into account as key decision-making criteria when selecting the new equipment to be installed.

4.2.4.3. Partial climate adaptation assessment

The partial climate adaptation assessment consists of the following two phases:

1. Screening phase (assessment of the impacts of climate change on infrastructure):

   The purpose of the screening phase is to determine the nature and extent of the impacts that climate change is expected to have on the infrastructure development to be implemented under the project.

   The screening itself is divided into three sub-processes, which are as follows:

   1.1. Assessment of the climatic exposure of the project site.

   1.2. Determining vulnerability to climate change in relation to the project's scope and expected outcomes.

   1.3. Based on a comparison of the results of the two previous assessments, identify the impacts of climate change on a given infrastructure development and on the maintenance of its outcomes.

2. Detailed analysis phase (risk assessment of infrastructure in relation to climate change, identification of adaptation measures):

   This is only required if the results of the screening phase indicate that climate change is likely to have a significant impact on the implementation of the project or the operation of the infrastructure to be built. The assessment involves examining the likelihood of the

significant climate change impacts identified during the screening phase and determining the adaptation measures necessary to improve resilience.

The following are some of the key points regarding the methodology and specific implementation aspects of the climate adaptation sub-assessment carried out in connection with the SSLE of the Paks NPP:

- Since this is an existing facility, no major construction work is required, and no GHG releases associated with such work are expected.
- Even taking into account the expected cost of construction, the project's return on investment is assured even under unfavourable conditions.
- As a result of the detailed site inspection and assessment of the NPP in accordance with nuclear regulations, as well as the work carried out during the preparation of the PCD and EIAR, the inspection was conducted based on site-specific data.
- As a result of the detailed site investigation and assessment required for nuclear licensing, it is possible to exclude numerous climate change impacts from further consideration by assigning them a well-founded "not relevant" classification during the site exposure assessment.
- In addition to the climate change impacts outlined in the Guideline, further climate change impacts specific to NPPs were also examined.

During the screening phase, an assessment of the site's climate exposure identified the following climate change impacts as relevant, with low current and projected future impacts:

- Based on an assessment conducted in accordance with the criteria set forth in the Climate Resilience Guide:
  - expected change in the annual average temperature (slow increase),
  - expected change in average summer temperature,
  - the expected change in the number of hot days,
  - an increase in the number of days with heatwaves.
- Based on an assessment conducted in accordance with specific NPP criteria:
  - a decrease in the Danube's water discharge due to an increase in the maximum duration of dry periods within the catchment area.
  - the rise in the water temperature of the Danube.

Based on the above, two groups of impacts have been identified, regarding which the following conclusions can be drawn from the facility's vulnerability assessment:

- The facility is not vulnerable to the set of climate change impacts associated with rising air temperatures. These impacts have been managed throughout the facility's operation to date, and available projections have not indicated any changes that would prevent the management of these climate change impacts in the future.
- An ultra-conservative estimate has been prepared regarding the climate change impacts associated with the decline in the Danube's cooling potential. Based on this estimate, and applying the categories specified in the guidelines, the magnitude of the risk to the facility falls into the "low" category under current operating practices.

The analyses conducted as part of the screening phase indicate that the expected impact is not significant for any of the climate change scenarios. Therefore, there was no need for a further detailed climate adaptation analysis, taking into account the recommendations of the guideline.

In addition to confirming the NPP's compliance with climate adaptation requirements, the individual analyses also highlighted that, from an economic perspective, there may still be significant differences even when addressing climate change impacts classified as being in the "low" category, thanks to the high unit capacity of the NPP units and the outstanding efficiency of SSLE. Therefore, provided that the cost-benefit ratios are appropriate, it is advisable to prepare for managing extreme situations that go beyond the acceptance criteria of the climate adaptation assessment, provided that this is economically justifiable and technically feasible. Taking these factors into account, the following optimization recommendation has been formulated: for the group of climate change impacts related to rising air temperatures, it is recommended to establish,

review, or optimize business continuity plans that optimize technological cooling capacities in the event of potentially extremely high air temperatures, particularly in conjunction with simultaneously extremely high Danube water temperatures, thereby ensuring the climatic conditions necessary for the operation of the equipment.

With regard to the set of climate change impacts related to the decline in the Danube's cooling potential, studies were conducted to identify potential technical solutions that could be used to optimize the number and extent of water releases required to protect the Danube from thermal loading. The proposed technical solution involves the construction of the alternative warm-water channel section and the connected peak cooling system, which will significantly reduce the temperature of the warmed cooling-water before it is discharged into the Danube (*Chapter 2.2.2.1.*).

Overall, it can be stated that the climate protection rationale for the SSLE is based on the fact that, in line with European Union and national energy and climate strategies, the NPP's SSLE – taking related activities into account – will result in low GHG releases during the implementation period, as it involves the timely extension of the production capacity of an existing facility. Furthermore, from a climate protection perspective, it is equally significant that the NPP will continue to operate as a facility with outstanding climate protection characteristics throughout its extended service life, thanks to the extremely low carbon footprint per unit of electricity generated by the plant[7]. The analysis confirms that the facility's climate adaptation characteristics are exceptional; the robust design typical of NPPs and the significant safety margins are important not only in the face of other human-made and natural hazards but also in terms of adapting to the effects of climate change.

4.2.4.4. Impact of the planned activity on the ability of the potential impact area to adapt to climate change

Climate change adaptation capacity refers to a system's ability and readiness to prepare for climate change, mitigate expected damages, manage the consequences of events as they occur, and adapt to changes. When assessing the impact of a planned activity on the area's adaptive capacity, it is necessary to examine whether the activity in question affects the vulnerability and adaptive capacity of the facilities and infrastructure located in the vicinity of the site. A given activity may alter the microclimate, transform wind corridors or affect surface or groundwater resources. It is necessary to assess whether the planned project could increase the frequency of climate change-related risks or the magnitude of their impacts.

The presumed area of environmental impact resulting from the operation of the Paks NPP (the area within a radius of approximately 10 km from the plant) extends into the counties of Tolna and Bács-Kiskun. The affected area is primarily agricultural in character and is used by the agricultural sector; the second most significant sector is forestry and forest management. The vast majority of the affected settlements are villages with populations ranging from nearly 450 to 4,000, characterized by rural, single-family housing and a high proportion of green spaces. The exceptions to this are the two small towns of Paks (population 17,827) and Kalocsa (population 14,619). However, even in these settlements, the dense, metropolitan-style development, tall buildings, and extensive paved areas are not typical; with the exception of a few housing estates, the small-town, suburban environment is the dominant feature. In terms of infrastructure and industry in the area, the town of Paks, the power plant site, and the Paks Industrial Park are particularly noteworthy. In addition, the agricultural processing industry plays a significant role in the region. The region is characterized by transportation infrastructure (primarily the road network /Main Road No. 6, M6 Motorway/, railways, and the Danube as a waterway) and elements of the high-voltage power transmission network.

[7] Greenhouse gas releases over the entire life cycle of the Paks NPP amount to 11.1 g of CO_2 equivalent per 1 kWh of electricity generated.

The climate change adaptation objectives and planned measures are set out in the county climate change strategies, taking into account the sensitivity and vulnerability of each county's territory to the impacts of climate change.

According to Tolna County's climate change strategy, the factors shaping the county's vulnerability to climate change are primarily drought (agricultural production), heatwaves (society, public health), storms (built environment), water-related hazards (e.g., flash floods, water erosion), and threats to natural values (biodiversity loss).

The climate strategy also notes that in Tolna County – which is primarily an agricultural region facing unfavourable demographic trends – the investment associated with the expansion of the Paks NPP could significantly mitigate the adverse effects of climate change, through its positive effects on the county's socio-economic situation.

The climate strategy defines the establishment of a county-level climate protection institutional framework and the securing of its funding as the overarching climate protection objectives for Tolna County; it sets forth the following as mitigation objectives – that is, objectives aimed at reducing the release of GHGs that cause climate change into the atmosphere:

- improving energy efficiency by reducing release,
- increasing the share of renewable energy sources in the local energy mix,
- reducing CO_2 releases from transportation,
- expanding forest areas.

The county climate strategy includes the following adaptation and preparedness objectives:

- Comprehensive adaptation and preparedness objectives (e.g., expanding areas protected from drought, reducing vulnerability to flood damage, mitigating the effects of heatwaves, reducing the vulnerability of the built environment, and increasing green spaces).
- Specific adaptation and preparedness objectives (e.g., assessing the vulnerability of natural and landscape assets and protected sites; creating the conditions for climate change adaptation in wine-growing regions).
- Climate awareness and awareness-raising objectives (e.g., shaping consumer behaviour, expanding knowledge of adaptation, raising awareness to reduce GHG releases, and strengthening the municipality's climate-conscious communication).

According to Bács-Kiskun County's climate change strategy, climate change is felt most acutely in the county through increasing water shortages and intensifying summer heat; accordingly, it primarily affects those sectors and fields that are particularly sensitive to these changes, namely agriculture and forestry, water management, disaster prevention, nature conservation, and public health. The climate strategy has defined the following climate protection objectives:

- Releases reduction and decarbonization targets (reducing GHG releases from building operations, transportation, agricultural practices, and the waste sector).
- Adaptation and preparedness objectives (e.g., developing a heatwave response plan for the municipality to reduce public health risks, maintaining the natural condition of protected habitats, water management practices aimed at water retention, soil management practices aimed at improving soil organic matter content and water retention, maintaining and improving forest health, and partially renovating or comprehensively refurbishing the building stock).
- Objectives related to awareness-raising, climate awareness, and institutional development (e.g., improving access to up-to-date information on climate change; preparing strategic planning documents that identify the expected local impacts of climate change and the associated tasks; increasing the number of businesses engaged in research and development activities related to environmental and/or climate protection, and disseminating knowledge about climate-conscious consumption habits and lifestyles to the general public.

With regard to the SSLE of the Paks NPP, it can be concluded that the existing environmental impacts will essentially continue to apply in the future. The planned activity will require the use of new areas due to the route of the proposed alternative warm-water channel and the land occupied

by the intermediate cooling structures. The construction of new structures and facilities will also involve the use of green spaces and forested areas in the immediate vicinity of the NPP. However, the use of these currently undeveloped areas will not be on a scale that would substantially or noticeably affect the region's capacity to absorb greenhouse gases.

The NPP site is located further away from the residential areas of Paks, outside the densely built-up urban environment where the effects of climate change pose a greater problem; consequently, the heat island effect resulting from the existing built-up area cannot be considered significant. Although the climate impacts resulting from the power plant's operation are detectable, they are local in nature, and mesoclimate changes cannot be assumed.

With regard to water use, water extractions, and the impact on water resources, the SSLE will also not result in any changes compared to the current situation. Due to the SSLE, runoff conditions at the power plant site and in its surroundings will change only to a minor extent, specifically in the areas affected by the alternative warm-water channel section and the intermediate cooling structures. In all other respects, the planned activity will be carried out at the existing site using the structures, equipment, and infrastructure elements already in place.

Because of the technology used to generate electricity at the NPP, no GHG releases are released into the atmosphere; thus, the continued operation of the NPP contributes significantly to the long-term maintenance of electricity generation that does not involve GHG releases.

The sensitivity of regional infrastructure elements (transportation, power lines, and other industrial activities) to climate change, as well as their ability to adapt, will not be affected by the SSLE of the NPP; it has no impact on them.

However, the continued operation of the NPP ensures reliable, stable, and predictable baseload electricity generation to reliably meet growing electricity demand. Through its continued operation, the Paks NPP contributes at the national level to increasing the country's ability to adapt to the expected impacts of climate change. Furthermore, through the maintenance of industrial activity and the power plant company's social engagement, it can play a role in shaping public perception and in maintaining the region's economic strength in the long term.

The extension of the service life of the Paks NPP does not conflict with the adaptation objectives and measures listed above, as set forth in the climate strategies of Tolna and Bács-Kiskun counties, nor does it hinder their implementation, and does not have an adverse effect on the ability of the presumed impact area to adapt to climate change.

4.3. Assessment of impacts on surface waters

The ecological status of the Danube and surrounding surface waters was examined and assessed based on the physical, chemical, and bacteriological characteristics of the water and sediments, as well as on the biological components, including phytoplankton (PP), phytobenthos (PB), macrozoobenthos (MZB), and fish communities. Zooplankton (ZP) was also included in the assessment – even though it is not among the biological elements required to be assessed under the Water Framework Directive (WFD) – because this group serves as a good indicator of the nutrient cycle status of water bodies.

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, along with an evaluation of the impacts of an alternative warm-water channel with a new discharge point and the connected peak cooling system.

The purpose of the studies conducted in 2024 is to assess the ecological status of the relevant sections of the Danube (AOC754, AOC755) in accordance with the WFD, to conduct an ecological analysis of each biological components, along with an analysis of the current impacts of the Paks NPP's non-radioactive discharges – particularly its heated 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 groups of organisms, and an assessment of the baseline

conditions under current operations. The studies covered the main channel of the Danube between river kilometre 1544 and 1474, which falls within two water bodies: (1) AOC754 – the Danube between Dunaföldvár and the Sió mouth (directly affected by discharges from the Paks NPP); (2) AOC755 – the Danube between the Sió mouth and the national border (indirectly affected by discharges from the Paks NPP via the AOC754 water body). In addition to the main channel, the assessment of biological elements also covered one sampling section each of the four major side arms of the affected downstream section: (1) Uszódi-mellékág, (2) Grébeci-Holt-Duna), (3) Rezéti-Holt-Duna, (4) Vén-Duna. The hydrological and biological investigations conducted in 2025 took place on the section of the Danube near the NPP (1544-1520 rkm). A map showing the sampling sites is presented in *Figure 4.3-1.*

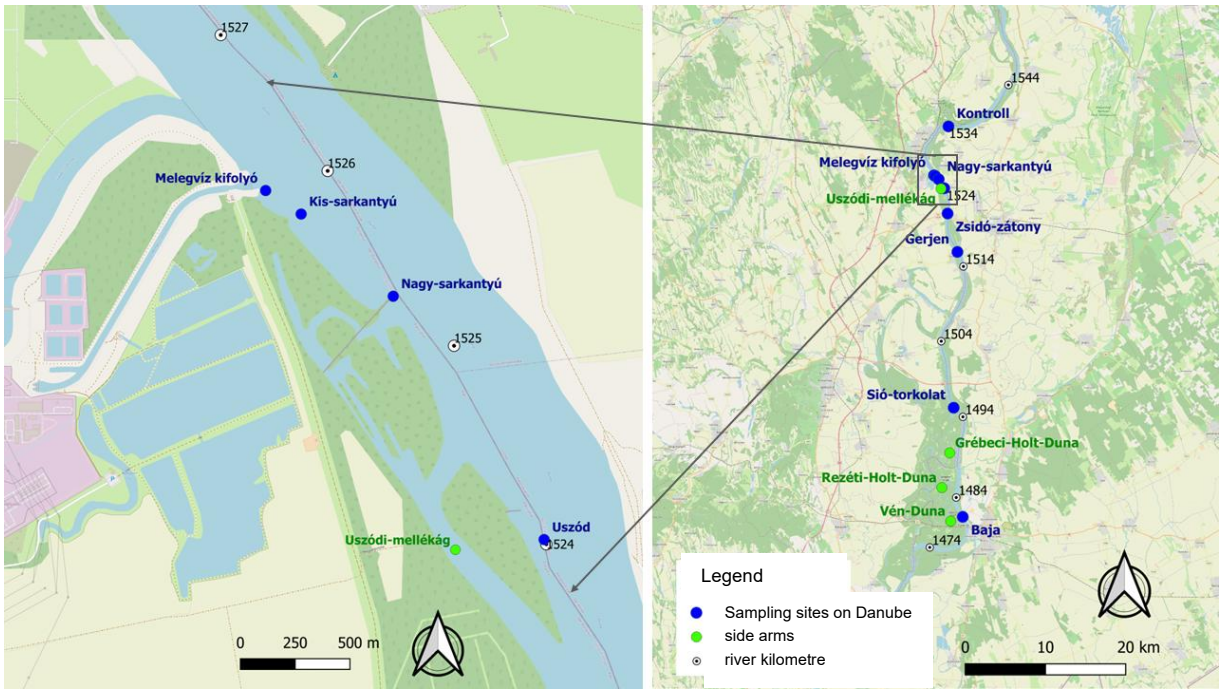


Figure 4.3-1. Overview map of the assessment sites

The sampling sites of the physical chemical and bacteriological examinations are presented in *Table 4.3-1.*, while the sampling sections of the biological studies are presented in *Table 4.3-2*.

Table 4.3-1. Sampling sites of physical, chemical, and bacteriological examinations

No.	Cross-section position / Monitoring number	Danube river kilometre, name of locality
1.	Control Upstream 1 cross-section	1533.6 rkm Paks ferry
2.	Outfall 2 cross-section	1526.0 rkm Warm water
3.	Close Downstream 3 cross-section	1525.3 rkm Large groin
4.	Close Downstream 4 cross-section	1524.7 rkm Uszód
5.	Downstream 5 cross-section	1520.0 rkm Zsidó-reef
6.	Downstream 6 cross-section	1515.8 rkm Gerjen
7.	Far Downstream 7 cross-section	1496.0 rkm Sió-South
8.	Far Downstream 8 cross-section	1478.7 rkm Baja road bridge

Table 4.3-2. Sampling sites of biological elements

Test sections for phytoplankton, phytobenthos, zooplankton, and macrozoobenthos	Fish sampling cross-sections
1. Control (upstream) (1544-1527 rkm)	1. Control (upstream section) (1544-1527 rkm)
2. Warm water outfall (warm water) (1526.2-1525.9 rkm)	2. Warm water outlet (warm water section) (1526.2-1522 rkm)
3. Kis-sarkantyú (close downstream 1) (1525.9-1525.5 rkm)	3. Zsidó-zátony (mid-field downstream section 1) (1522-1518 rkm)
4. Nagy-sarkantyú (close downstream 2) (1525.5-1524.5 rkm)	4. Gerjen (mid-field downstream section 2) (1518-1510 rkm)
5. Uszód (close downstream 3) (1524.5-1520 rkm)	5. Sió-dél confluence (far downstream section 1) (1497.2-1490 rkm)
6. Gerjen (intermediate downstream) (1518-1510 rkm)	6. Baja (far downstream section 2) (1490-1474 rkm)
7. Sió-dél (far downstream 1) (1497.2-1490 rkm)	–
8. Baja (far downstream 2) (1490-1474 rkm)	–

4.3.1. Assessment of the physical and chemical and bacteriological characteristics of water and sediment

As part of the investigations carried out in 2024, water samples were collected at eight sections of the Danube – three vertical profiles per section (left bank, centre, right bank) – and four times a year (April, May, July, October) for the purpose of conducting physical, chemical, and bacteriological analyses of the water. The investigations covered the assessment of basic chemical components relevant to the WFD, as well as metals among specific pollutants, in the affected Danube water bodies (9K, 10A), as specified in the RBMP3 guidelines. While these factors are of paramount importance for assessing releases from the Paks NPP, components not covered by the WFD assessment – specifically water temperature, chlorophyll-a, and petroleum hydrocarbons (TPH-GC) – were also evaluated within the scope of the investigation program. During the investigation, Danube sediment samples were also analysed at eight Danube cross-sections on both the right and left banks, corresponding to the locations of the water chemistry sampling. The sediment analysis covered total petroleum hydrocarbons (TPH-GC), polycyclic aromatic hydrocarbons (PAH), and polychlorinated biphenyls (PCB).

Among the basic chemical components of the WFD, the impact of releases 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, total nitrogen among the nitrogen forms examined, it was determined that the NPP's releases have a minor local impact on the nitrogen regime in the immediate downstream section on the right bank. However, on the one hand, this impact does not result in a deterioration by one status class even in the immediate vicinity of the discharge, and on the other hand, factors independent of the NPP's discharge – specifically, the hydro morphological characteristics of the sidearm, as indicated by ecological analyses – play a more significant role in the nitrogen regime of this section. The discharge of warmed cooling-water from the NPP, in addition to the N-flow, clearly influenced the level of oxygen saturation in the warmed section of the Danube. However, this change also did not cause a class-level change in water quality, even in the area immediately downstream of the discharge. With regard to other basic chemical components, no changes attributable to the NPP's discharge were detectable based on a detailed evaluation of the sampling sites.

A comparison of the results of the investigations carried out with the data from the core monitoring network sampling shows that they confirmed the findings of the investigations in every respect. When comparing the test results with archival data, improvements in water quality have been observed over the past decades across the entire section of the Danube under investigation, primarily with regard to the component groups of nutrients, acidification, and oxygen balance (specifically, the elements indicating organic matter load).

According to the chemical status assessment conducted under the WFD framework based on groups of key chemical components, the 2024 survey indicated high chemical status for all eight sections with respect to every component.

However, based on the specific pollutants assessed, it was determined that, of the eight sections of the Danube examined, only the lead levels met the criteria for good chemical status. For arsenic, zinc, chromium, copper, cadmium, mercury, and nickel, water quality at one or more points failed to achieve good chemical status specified in RBMP3. However, detailed analyses revealed that the lower chemical status observed at the sections cannot be linked to releases from the Paks NPP; the source of the exceedances observed in the immediate downstream area is located upstream of the city of Paks. The likely cause of the pollution levels indicating extreme values is a one-time or intermittent discharge of wastewater with high concentrations.

The discharge of warm-water from the Paks NPP into the Danube clearly has the most significant impact in terms of thermal load. As a result of the discharge of warmed cooling-water, 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 thermal gradient toward downstream was significant even over short distances; at the sampling point on the right bank at Nagy-sarkantyú (Large Groyne) (1525.3 rkm), this gradient averaged 6.5°C. Thereafter, the rate of temperature decrease gradually slows and extends over a greater spatial area.

The investigations confirmed, in line with the model results, that the warm-water plume remains mostly on the right bank side of the Danube. The model results and the examination results also indicate that the spatial distribution of the heat plume (both longitudinally and horizontally) is influenced by both the water flow and the background temperature. Thus, the critical conditions in terms of thermal load are high background temperature and low water conditions.

Based on chlorophyll-a levels, the section of the Danube under examination varied between oligotrophic and mesotrophic conditions throughout the year. An analysis of the seasonal variation in chlorophyll-a shows that it reaches its annual maximum as early as April: The Danube is already in a mesotrophic state during this period. Samples from May and August showed concentrations very similar to those in April. By October, chlorophyll-a concentrations had decreased significantly along the entire section. At this time, the Danube water could be classified as oligotrophic at all sampling points.

Analysis of the water's total petroleum hydrocarbons (TPH-GC) content indicated an occasional, minor, and local impact from the Paks NPP. The single, elevated TPH value observed at the discharge point did not result in a deterioration of water quality by one status class at the sampling site, nor did it extend to the area of the subsequent sampling cross-section. However, the increase in polycyclic aromatic hydrocarbons (PAHs) observed at the sampling site on the right bank of the warm-water discharge during the sediment analysis confirmed this periodic power plant impact.

In addition to the parameters described above, the monitoring program also included the analysis of the following chemical components: (a) total suspended solids, (b) alkalinity, (c) iron, (d) manganese, (e) sodium, (f) potassium, (g) magnesium, (h) calcium, (i) carbonate, (j) bicarbonate, (k) total hardness, (l) sulfate. No impact of emissions from the Paks NPP could be detected with respect to these components.

Overall, the bacteriological tests indicated that the colony counts of Coliform and faecal Coliform bacteria, as well as 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 colony counts that were an order of magnitude higher. In addition to water temperature, water discharge may also play a role in this phenomenon. Based on fecal contamination levels, the impact of the Paks and Kalocsa-Baráka 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 colony counts of Salmonella, psychrophilic and mesophilic bacteria, and Clostridium aeruginosa did not show any significant seasonal variation. None of the groups examined showed a trend-like distribution along the longitudinal profile. Based on the evaluation of the sampling sites, the impact of emissions from the Paks NPP was also not detectable for any bacterial group.

4.3.2. Biological assessment of the investigated surface waters

Analysis of 96 phytoplankton samples collected in 2024 from the examined section of the Danube confirmed the presence of a rich microflora. The floristic composition corresponded to what is generally observed in large potamal rivers; i.e., a high proportion of diatom and green algae taxa. 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 occurred in less than 5% of the samples.

The structure of the communities observed in the examined section of the Danube was assessed using multivariate analyses based on the biomass share of the groups. The purpose of these analyses was to explore the relationship between environmental background variables and the communities. The biomass share of individual algal groups presented a completely different picture than the floristic composition. Diatoms accounted for the vast majority of the biomass. The biomass share of the other groups was negligible, amounting to less than 5%. Based on multivariate analyses, it was concluded that the phytoplankton of the Danube in the studied section is not subject to influences that would result in measurable differences in composition. Nutrients and temperature also have only a minor effect on the structure of the community. The oligotrophic character of the river may be influenced by factors such as current light conditions and sedimentation resulting from river impoundments in the upper reaches.

The results of examinations carried out in 2024 confirmed that the phytoplankton of the Danube 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 the phytoplankton. The minor shifts observed in the dominant taxa did not affect the river's ecological status, as expressed by the EQR value.

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

The sidearms connected to the Danube form two groups based on their phytoplankton dynamics and composition. The Uszódi-mellékág and the Rezéti-Holt-Duna, which are connected to the Danube, as well as the (Vén-Duna), had plankton with a composition nearly identical to that of the main channel and a similar biomass. The more isolated Grébeci-Holt-Duna clearly exhibited a lacustrine character, in terms of both its quantitative relationships and its dynamics and composition. No differences in phytoplankton composition or abundance attributable to thermal loading were observed in any of the sidearms.

Sampling of the benthic diatoms (phytobentos) was conducted in 2024 at the designated 8 cross-sections, at a total of 16 sampling points (one on the right bank and one on the left bank at each cross-section), on three period (May, August, and October). The assessment were conducted in accordance with currently applicable domestic and international standards and regulations.

The structure and species richness (number of taxa) of the diatom community forming the surface layer showed no spatial variation: no statistically significant differences were detected with respect to either sampling location or degree of disturbance. However, natural seasonal variations were evident.

The water quality ratings for the sampling points, determined based on the IPS diatom index, can be calculated as their average. Based on these results, it was determined that, of the 16 sampling points examined, 7 had good water quality and 9 had moderate water quality. At locations affected by warm water discharge (4 points, 12 sampling events), the quality was moderate in all cases based on the annual average IPS values. At the other sampling points, moderate and good ratings occurred with equal probability.

Despite the above, however, based on the annual average EQR values, there was no significant difference either between the sampling sites or between the AOC754 and AOC755 water bodies. In contrast, the annual average rating of the affected section exposed to the warm water discharge was significantly lower than the ratings of the control (upstream and left bank sites until Uszód) and the sections considered unaffected (Gerjen-Baja).

The classification values confirm the local impact of the heated water discharge, with the caveat that groynes disrupt the riverbed morphology in the affected section. The decrease in flow velocity at the groynes causes changes on microhabitat level. Additionally, on a micro-scale, the physical and chemical parameters of the water may differ from those of the main channel, albeit only slightly. The emergence of these combined conditions creates opportunities for the local enrichment of primarily, but not exclusively, limnophilic species that favor slow flow and/or prefer higher conductivity and trophic levels. The discharge of heated cooling-water can amplify these local effects.

With the exception of the Rezéti-Holt-Duna, which was in good ecological condition, the sidearms examined are in moderate condition. However, no significant differences can be detected based on their phytobenthos-based assessment. Likewise, no statistically significant differences were found among the sidearms based on their community structure. At the same time, from a biological perspective, the separation of the Grébeci-Dead-Danube from the other sidearms clearly indicates its more enclosed, stagnant nature. The seasonal analysis also does not indicate any clear trend-based changes in the phytobenthos composition or classification of the sidearms. No impact related to the discharge of cooling-water from the Paks NPP could be detected in the sidearms, not even in the Uszódi-mellékág, which is closest to the discharge point.

Quantitative zooplankton (ZP) 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, surveys were also conducted in the four sidearms. The results of sampling are suitable for the ecological characterization of the Danube and the four sidearms with different habitats, as well as for the ecological assessment of emissions from the Paks NPP.

The assessment identified a total of 26 rotifers, 24 cladoceran taxa, and all three orders of copepods. The zooplankton communities found in the examined section of the Danube were typical of the river. The three non-native species present have been part of the domestic zooplankton fauna for long time.

The communities that formed corresponded to seasonal dynamics, and their composition was primarily influenced by seasonal effects. The numbers of individuals and taxa showed a slight increase downstream, while biomass values were particularly high at the section below the Sió River (DZP7). The nutrient-rich inflow waters from the Sió River and the Gemenc side-arm system, which are also richer in planktic organisms, may have a fundamental influence on the composition of the zooplankton community at the two lowest monitoring sites examined (DZP7, DZP8). Based on community structure indicators, the discharge of cooling-water from the Paks NPP has no detectable effect on the zooplankton community.

According to the diversity analyses, there is no difference in zooplankton diversity among the sampling sites. However, the diversity profiles indicate a slight variation in diversity among the directly affected sampling sites, which is reflected in higher diversity among the dominant species.

Based on a multivariate statistical analysis of environmental background variables, it can be concluded that the zooplankton community is primarily organized according to seasonal patterns. In addition, water discharge and the resulting changes in chemical characteristics represent a significant driving force in community organization. Although temperature also strongly influences community structure, it clearly reflects seasonal variations. Based on the multivariate analysis, no effect of the warmed cooling-water was detected. The environmental and biotic characteristics of the samples directly affected by the discharge did not differ significantly from those of the control sites or sites not directly affected.

Zooplankton is not among the groups to be assessed under the WFD. However, as the most significant primary consumers in aquatic ecosystems, they are important indicator organisms in our waters. Since no WFD-based classification system is available, it is advisable to assess the status of the examined sections of the Danube based on the previous saprobiological system. Based on this, it was determined that the studied sections of the Danube exhibit characteristics ranging from oligosaprobic to beta-mesosaprobic, and their status is good. The studied sections show no differences in this regard either.

Of the side arms examined, the Grébeci-Holt-Duna differed significantly from the zooplankton communities of the other side arms in terms of species richness. This is explained by side arm's status as a standing water body and its correspondingly higher productivity. Based on their zooplankton communities, the side arms 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. This is consistent with the evaluation of data from 2002-2003.

In 2024, surveys of aquatic macroinvertebrates (macrozoobenthos, MZB) were conducted at eight cross-sections of the Danube between Paks and Baja on three sampling period (May, August, and October). Quantitative sampling was conducted at a total of 16 Danube sites (8 cross-sections on the left and right banks) and 4 sidearms in accordance with the Hungarian methodological protocol of the WFD.

A total of 67 taxa were identified during the examinations. The dominant species in the community were *Lithoglyphus naticoides*, *Paramysis lacustris*, *Limnomysis benedeni*, and various Dikerogammarus species. These five species accounted for nearly 90% of the total number of individuals, while more than half of the taxa occurred rarely (with fewer than 50 individuals). The composition accurately reflects the stable macroinvertebrate community characteristic of the middle section of the Danube.

Within the scope of the examination, four protected species were identified: *Stylurus flavipes*, *Borysthenia naticina*, *Fagotia acicularis*, and *Fagotia esperi*. Of these, *Stylurus flavipes* was the most widespread, occurring in all transects, while the presence of the other species was concentrated locally, mainly in the vicinity of Uszód and Paks. The only qualifying species designated for the Tolnai Duna (HUDD20023) Natura 2000 site from a macroinvertebrate perspective, *Unio crassus*, was not found in 2024; it was last observed in the surveyed section in 2015. Anisus vorticulus, the qualifying 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 recorded species belong to this group, and they account for approximately 40% of the total number of individuals.

The number of species (14-26) and abundance (694-24,620 individuals/m^2) showed considerable spatial variation among sampling sites. Differences between the control sites and those affected by warm-water discharge were statistically significant for several community indices. Community responses were primarily manifested not in a decrease in species richness, but in a shift in dominance and abundance relationships. According to the results of canonical correspondence analysis (CCA), water temperature had the most significant effect on community structure. In particular, the sampling site on the right bank of the warm water discharge (DMZB2J) deviated markedly in the ordination space, where community structure was strongly associated with environmental factors related to the discharge – indicating that thermal load has a clearly detectable community-shaping effect here.

The long-term comparison was based on the results of archival data collected using a standardized methodology and taxonomic resolution. A total of 124 taxa were identified, but only 28 species were recorded every year, indicating a stable core fauna characteristic of the middle section of the Danube. During the 2024 examination, several new species appeared (e.g., *Anodonta anatina*, *Orthetrum cancellatum*), while several previously recorded species were absent. This confirms that sampling in a single year captures only a subset of the community, and that repeated sampling over time is necessary to assess full diversity and long-term changes.

To provide a comprehensive ecological assessment, a supplementary survey was conducted in 2025 in addition to the 2024 examination. The results of the two examinations essentially corroborate one another, but they also clarify in several respects the effects of environmental factors that actually impact MZB communities. An increase in dominance was observed in areas affected by warm-water discharge. The examinations show that water temperature and temperature surplus (ΔT) are among the factors influencing community structure, but their effects are highly habitat-dependent. Community differentiation is primarily determined by the measured ΔT, the degree of impact, and substrate structure – particularly the presence of larger stone fractions (6-40 cm) – suggesting that the effect of thermal load is manifested in conjunction with

substrate and flow conditions. The 2025 results confirm previous findings and further support the context-dependent nature of thermal load on habitats, even along finer spatial and temperature gradients. Ecological point of view, warm-water discharge does not cause the collapse of the affected community, but its impact is detectable locally at the level of certain community and indicator metrics.

Based on the 2025 community-level threshold analyses, a range of change around $\Delta T \approx 2.1°C$ can be identified that indicates the onset of community restructuring. This indicates that consistent community shifts can be observed even with a relatively small temperature increase, although these shifts do not occur uniformly across all habitat types. The effect of the thermal gradient is primarily expressed in areas with low flow, limited mixing, and fine-grained substrates, while its impact is more moderate in habitats with coarser substrates and faster flow.

Among the sidearms, the Grébeci-Holt-Duna proved to be the most species-rich (44 taxa), while the Uszódi-mellékág had the lowest number of species (26 taxa). Based on the NMDS results, the communities of the sidearms were well separated from the main channel samples, particularly in the case of hydrologically isolated, plesiopotamon-type habitats (e.g., 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 ecological status of the water body between Dunaföldvár and the Sió mouth (AOC754) is moderate based on macrozoobenthos, while the water body between the Sió mouth and the national border, designated AOC755, is in poor condition. An analysis of seasonal EQR values shows that EQR values for spring samples were lower, which can be attributed to high water levels in the spring. The standard deviation of the EQR values for the entire data set is 0.11, while excluding the spring samples reduces it to just 0.05, indicating the stability of the Danube's condition. The EQR results confirm the findings of the ecological analyses.

The survey on fish assemblages was conducted in 2024 at a total of six sections using quantitative sampling in accordance with the WFD. Field works were conducted in the riparian (shoreline) region of each section using an electric fishing gear (EFG), while in the benthic region, an electric trawling gear (ETG) was used as a supplementary method 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. Sampling in both years was conducted in accordance with international and national standards and regulations, with daytime sampling as in previous years.

During the 2024 ichthyological survey, a total of 11,254 individuals belonging to 44 species were identified in the Danube main channel. A total of 34 species were found in the sidearms. During sampling conducted on the Danube in the summertime by EFG, juvenile specimens of a total of 31 species were found. This high proportion confirms that the greater number of juvenile species is associated with higher water levels. Juveniles of a total of 24 species were detected in the sidearms.

Based on the data, it was determined that the results of the 2024 sampling are suitable for drawing appropriate conclusions from a taxonomic and ecological perspective. The species composition of the studied sections is essentially homogeneous and, when compared with the results of previous investigations, shows a high degree of similarity to them. At the same time, while the populations of some species have fluctuated over the past two decades, the abundance of several species has changed more significantly. The 2024 examination also confirmed that, due to the discharge of warm-water, there is no species that cannot find suitable living conditions in the affected section. It was also established that higher water levels result in a higher overall number of species and a more even distribution of species composition in the Danube, due to more diverse habitat conditions and more favourable spawning conditions. The fish species composition of the studied side arms shows fundamental similarities to that observed in the main channel of the Danube. However, it differs from it to a lesser, varying degree depending on the stability and strength of their connection to the main channel.

During sampling, a total of three highly protected species (*Eudontomyzon mariae*, *Zingel zingel*, *Zingel streber*) and seven protected species were detected at the Danube sampling sites (*Alburnoides bipunctatus*, *Rutilus virgo*, *Leuciscus leuciscus*, *Rhodeus amarus*, *Romanogobio*

vladykovi, *Gymnocephalus baloni*, *Gymnocephalus schraetser*). Five species under nature conservation protection were found in the side arms: *Rutilus virgo*, *Rhodeus amarus*, *Romanogobio vladykovi*, *Gymnocephalus baloni*, and *Gymnocephalus schraetser*. Here, reophilic protected species were found only in the more permanent Danube-connected side arms, typically eupotamon or parapotamon.

Of the 11 priority fish species in the Tolnai Duna (HUDD20023) SAC area, 8 were found during sampling (*Eudontomyzon mariae*, *Rutilus virgo*, *Leuciscus aspius*, *Romanogobio vladykovi*, *Gymnocephalus baloni*, *Gymnocephalus schraetser*, *Zingel zingel*, *Zingel streber*). Of the 12 indicator fish species in the Gemenc (HUDD20032) SAC area, the presence of 9 priority species was confirmed at sampling sites in the main channel (*Eudontomyzon mariae*, *Rutilus virgo*, *Leuciscus aspius*, *Rhodeus amarus*, *Romanogobio vladykovi*, *Gymnocephalus baloni*, *Gymnocephalus schraetser*, *Zingel zingel*, *Zingel streber*).

Based on current and past surveys of the Danube, it can be clearly concluded that the ecological value of the surveyed section of the Danube is significant, taking into account both the number of protected fish species found here and, even more so, the structure of the fish assemblages. Stable populations of most protected rheophilic species are present in these sections of the Danube. Among invasive species, the population size of Gobiidae species continues to be dominant in the main channel of the Danube. At the same time, however, the successful spawning of the silver carp and its increasing invasion have also been observed in the section of the Danube under examination. While the sidearms are important spawning areas in the Gemenc section of the Danube, they also contribute to the release of several invasive species.

Based on the 2024 surveys, among the assemblage-structure indicators, species richness is homogeneous across the entire examined section of the Danube, during both the summer and autumn sampling periods. The results of sampling with an electric trawling gear indicate low species richness in the benthic region.

Based on the results of surveys conducted with the EFG during two periods (summer and autumn), it was found that abundance was highest in the warm water (DH2) section during both survey periods. However, no statistically significant difference at the 95% confidence level could be detected between the individual sections. The same pattern emerges from the analysis of abundance conditions in the benthic region. However, the comparison of sample units directly affected by warm water discharge and those not affected does indicate a statistically significant difference.

The results of the assemblage-structure analyses from the supplementary studies conducted in 2025 confirm the findings from 2024 while also refining them. It can be concluded that abundance is increasing in the areas affected by discharges from the Paks NPP. This increase causes a significant difference in riprap areas that provide a homogeneous substrate, while this effect to the same extent is not observed in areas with natural substrates. This also demonstrates that, in addition to temperature – or, more precisely, the magnitude of the thermal gradient (Δt) – the composition of the substrate also has a significant effect on community structure. Based on the results, it was also found that thermal load is reflected in the seasonal distribution of abundance. In autumn, higher population densities are characteristic of areas affected by warm water – regardless of substrate type. Water levels also influence the effects of thermal loading; during periods of low water, greater differences are observed between affected and unaffected sections. This clearly demonstrates that, in terms of the manifestation of thermal loading as an actual environmental factor, hydromorphological and hydrological characteristics at the microhabitat scale have a synergistic effect.

The results of the redundancy analysis confirmed that, in the areas affected by the discharge, both in the riparian and benthic regions, the elevated water temperature resulting from the discharge has a significant effect on the structure of the fish assemblages. In addition to the effect of the warmed cooling-water, the substrate composition and the community-organizing effect of the current are also detectable. Based on the supplementary examinations, it appears overall that the effects of thermal load interact with hydromorphological environmental factors, in which substrate type plays a decisive role. Artificial riprap provides a particularly important habitat for invasive species, which, in combination with thermal load, further accelerates the spread of these

species along the affected section of the Danube. At the same time, this finding highlights the importance of preserving natural habitat-types in order to achieve good ecological status in the Danube.

The results also highlighted the fact that the effect of the discharge is not constant in either time or space, but decreases in a gradient-like manner, meaning that the area affected is localized. On the one hand, it cannot be detected at the sampling sites on the left bank of the river, and typically, even at the sampling sites on the right bank, it does not extend across the entire area of the examined downstream sections. The survey results confirm that in the medial (benthic) region, the extent of the effect is comparable to that observed in the riparian area.

The results of the analysis of species traits indicated that the fish assemblages in the examined sidearms differ to varying degrees from those in the main channel, in close correlation with the strength of their connections to the Danube in the assessment area. Although the fish assemblages in the six examined sections of the main channel are similar, minor differences can be observed between them. In the DH2 and DH3 sections, which are directly affected by the discharge, rheophilic, benthic fish species dominate, while in the lowest section, DH6, a more diverse fish assemblage is characteristic due to the influence of the Gemenc sidearm system, with an increase in the proportion of stagnophilic metaphytic species alongside rheophilic species.

The ecological assessment for both periods indicates that the six sections of the Danube near Paks under review range from moderate to good condition, with no significant differences in the status of the individual sections. Overall, based on the evaluation of the summer samples, the status of both the AOC754 and AOC755 water bodies is good. 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 assemblage at water body scale.

The ecological status assessment of the sidearms shows that the three more open side arms are in good condition or very close to the “good” rating. The Grébeci-Holt-Duna, which is the most enclosed, has the poorest quality. Based on the assessment, the impact of emissions from the Paks NPP could not be confirmed in any of the side arms.

4.3.3. Assessment from the perspective of the Water Framework Directive

During the investigations carried out 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 ecological status assessment for both Danube water bodies under assessment (AOC754, AOC755) was completed in accordance with the guidelines established for RBMP3 Danube water body types (9K, 10A) (*Tables 4.3.3-1.* and *4.3.3-2.*). The assessment of chemical status extended beyond the basic groups of chemical components to include the evaluation of metals among specific pollutants. Zooplankton-based water quality assessment is not currently 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.

Based on the results of the 2024 investigations, the ecological status of the water body designated as the section of the Danube between Dunaföldvár and the Sió mouth, identified by code AOC754, is moderate overall. Based on expert estimates, the zooplankton is beta-mesosaprobic and in good condition. Among the specific pollutants tested in the water body, arsenic and chromium failed to achieve good chemical status.

The ecological status of the water body designated as the section of the Danube between the Sió mouth and the national border, identified as AOC755, is poor. In this section, this status is determined by the macrozoobenthos assessment in accordance with the “one out, all out” principle. However, it must be noted that the status of the water body, as determined by MZB, is practically entirely on the border 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 failed to achieve good chemical status.

Based on the assessments, it can be concluded that the Paks NPP has no detectable impact on water bodies; in other words, the plant's emissions do not cause any change in the condition of either the directly affected water body (AOC754) or the indirectly affected, more distant water body (AOC755).

Table 4.3.3-1. WFD classification of the two Danube water bodies under examination (EQR values in parentheses)

Quality elements	AOC754	AOC755
Physical and chemical component groups	High	High
Phytoplankton	Good (0.75)	Good (0.73)
Phytobenton	Moderate (0.57)	Good (0.64)
Zooplankton	Good (beta-mesosaprobic)	Good (beta-mesosaprobic)
Macrozoobenthos	Moderate (0.43)	Poor (0.397)
Fish community	Good (0.623)	Good (0.615)
Ecological status:	**Moderate**	**Poor**

Table 4.3.3-2. Assessment of the two examined water bodies of the Danube under the WFD based on metals

Metals	AOC754	AOC755
Arsenic (As)	Fail	Fail
Zinc (Zn)	Pass	Pass
Chrome (Cr)	Fail	Fail
Copper (Cu)	Pass	Pass
Cadmium (Cd)	Pass	Fail
Lead (Pb)	Pass	Pass
Mercury (Hg)	Pass	Pass
Nickel (Ni)	Pass	Fail

The results of the examinations are basically consistent with the values obtained from the analysis of archival data. Based on the chemical assessment, the analyses of community structure for individual groups of organisms, and the ecological status assessments, changes of varying magnitude and direction have been observed over the past period. Among these changes, the reduction in nutrient loading in the Hungarian section of the Danube is particularly noteworthy, as it has led to a decrease in phytoplankton biomass and, consequently, an improvement in the ecological status of planktic algae. However, climate change is causing adverse changes due to increases in water temperature and the lengthening of periods of extreme low water. These environmental changes are continuously eroding the structure of natural communities. The spread of invasive species – particularly macrozoobenthos (MZB) and fish species – along the entire Hungarian section of the Danube can largely be attributed to this. Based on the results of the analyses, hydro morphological conditions have not improved in the studied sections. However, together with changes caused by climate change, they also have an adverse effect on the status of certain groups of organisms. 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 hydro morphological conditions (PB, MZB, fish). It must be noted, however, that the changes in the ecological status of the examined sections of the Danube over the past two decades are not attributable to emissions from the Paks NPP, but rather to changes in the environmental conditions of the Danube on a regional scale. An evaluation of archival data and the results of the studies conducted indicate that, provided current emission regulations remain

in place, no water body-level impacts attributable to the operation of the Paks NPP are expected during its extended operation. The continued operation of the NPP does not jeopardize the achievement of good ecological status in the affected section of the Danube.

4.3.4. Impact assessment of the Paks NPP SSLE

4.3.4.1. Aspects of the impact assessment

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 impact factors, the expected impacts, the nature of the impacts, and the recipients of the impacts. All potential impact factors that could reasonably be associated with the SSLE have been listed. However, the assessment naturally focused exclusively on factors that actually impact the ecological status of the Danube.

With regard to impacts and impact areas, the relevant legislation distinguishes between direct, indirect, and transboundary impacts, as well as their respective areas. In defining direct and indirect impact areas, the direct impact area is defined as the area where the given impact can be detected or estimated. An indirect impact, and its area, is an impact that spreads further through the influence of an intermediary medium. The intermediary medium may be an abiotic environmental element (e.g. groundwater, soil, air) or a biological group (e.g. impacts propagated through the food web). The indirect impact area may be defined as the area within which population-level, ecologically interpretable complex aquatic material cycling processes can still realistically occur. At the same time, it is clear that the detectable areas of effects transmitted through biological processes in living systems typically overlaps each other. A good example of this is the interrelated effects of the thermal gradient and other hydro morphological conditions associated with emissions from a NPP. Of course, biological processes may involve impacts that can be considered indirect, the scope of which may even significantly exceed that of the direct impact. A typical example of such an indirect impact is the spread of invasive species. However, the direct link between these processes and the impact under examination cannot be measured objectively. Accordingly, they are not the subject of the impact assessment. Thus, for reasons of detectability, it is appropriate to assume that the scope of direct and indirect impacts is identical from the perspective of aquatic organisms during the impact assessment.

During the impact assessment, the nature of the impact was determined using a biotic-centred approach – that is, by examining it from the perspective of aquatic organisms, while also including humans as a recipient of the impact – based on its persistence, severity, and significance. Hydrological and water quality characteristics provide essential background information for the organism-centred impact assessment. While the biological elements of the Danube aquatic system can be considered the actual impact recipients, the hydrological changes identified through the analyses were also included.

Based on its duration, an impact can be short-term (up to a few months), medium-term (up to three years), or long-term (longer than three years). Based on its intensity – which applies to the habitat complex of the area of impact in ecological terms – it can be weak, moderate, or strong. Based on its significance – which, from an ecological and conservation perspective, also applies to the entire habitat complex of the affected area – it can be of low significance, of moderate significance, and of high significance. The ‘significant impact’ defined in Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures is equivalent to a high impact in this context. The categories of impact changes applied are presented in *Table 4.3.4.1-1*.

The impact assessment was prepared through a comprehensive evaluation of available archival data, the results of measurements and analyses conducted as part of the 2024 surveys, and the results of supplementary examinations carried out in 2025 to address specific issues.

In addition to examining the main channel of the Danube between Dunaföldvár and Baja (1544-1474 rkm), the impact assessment covered four Danube sidearms – the Uszódi-mellékág, the Grébeci-Holt-Duna (ANS503), Rezéti-Holt-Duna, Vén-Duna – as well as, based on archival

data, several oxbow lake water bodies: Faddi-Holt-Duna)(AIH066), Tolnai-Északi-Holt-Duna (AIH136), Tolnai-Déli-Holt-Duna (AIH135), and Bogyiszlói-Holt-Duna (AIH051).

Table 4.3.4.1-1. Categories of impact changes with regard to impacts on the Danube

Impact change category	Characteristics of the impact change
Improving	As a result of a beneficial effect, no entirely new habitat/community is formed. However, the ecological richness of the system increases, its habitat value and/or stability improves, and demonstrably positive changes occur in the populations of organisms characteristic of the original community.
Neutral	No classifiable state changes occur. The potential impact factor causes no evaluable physical, chemical, or biological/ecological change.
Tolerable	The impact factor causes detectable change in the receptor, but the effect remains minor (weak) even in the long term, and is therefore overall of low significance; it induces changes tolerable for the investigated biological system and remains within the limits of the system's self-regulating capacity. Within the legal framework, the impact does not result in category-level deterioration.
Burdensome	The impact factor causes detectable change in the receptor, and the intensity of the effect is moderate or strong; the impact is of medium or high significance. The effect generally persists only in the short term, while if long-term, its spatial extent remains limited. From the perspective of the investigated biological system, the effect is tolerable only if, although it exceeds the self-regulating capacity of the system, regeneration remains possible once the effect ceases. Within the legal framework, the impact may result in category-level deterioration.
Damaging	The impact factor causes substantial change in the receptor. The impact intensity is high. It may be medium-term, but is generally long-term, with larger spatial extent and stronger effects on the affected receptor community. Overall, it is of high significance. As a consequence, the affected community is substantially damaged and stabilizes into a new structure differing from the original one. The change is irreversible, meaning regeneration is not possible without human intervention. Within the legal framework, the impact results in category-level deterioration.
Eliminating	The impact factor is of high significance, as a result of which the original community ceases to exist, species characteristic of it disappear from the impact area, and either a new degraded community develops or, in more severe cases, the biota is completely destroyed in at least part of the impact area.

The impact assessment and the definition of the impact area were prepared for several scenarios: (1) the current operational condition of the Paks NPP, based on the operational characteristics of the period from the service life extension to the present; (2) The Paks NPP's continued, under independent operational conditions for the entire operating period of the SSLE, (3) the joint operating conditions of the Paks NPP and Paks II NPP for the entire operating period of the SSLE, and, among the planned alternative technical and regulatory factors, (4) the so-called "32/15 rule" (the temperature limit of the Danube water for the 500 m reference cross-section, permissible for reasons of security of supply, is a maximum of 32°C for up to 15 days */Chapter 2.3.2./*) during the independent operation of the Paks NPP, as well as regarding the operation of the (5) alternative warm-water channel section and the connected peak cooling system during the joint operation of the Paks NPP and Paks II NPP.

4.3.4.2. Impacts of warmed cooling-water discharged through the warm-water channel of the Paks NPP on aquatic communities

The chemical status assessment conducted in accordance with the WFD, based on physical and chemical analyses of the water, indicated that the chemical status of both Danube water bodies examined – AOC754, which is directly affected by the discharge, and AOC755, located downstream and thus indirectly affected – is high. Comparing the results of the investigation conducted in 2024 with archival data shows that over the past two and a half decades, the water quality of the examined Danube water bodies has significantly improved in terms of nutrient, acidification, and oxygen regime component groups – within the latter, fundamentally regarding elements indicating organic matter load. Based on the results of the investigations, it was determined that the emissions from the Paks NPP have no detectable impact on the chemical status at water body scale. Local effects associated with the discharge (inorganic-N, total-N) are at the limit of detectability. Moreover, environmental factors independent of the NPP's discharge play a more significant role in their occurrence.

Among the chemical components analysed, in addition to those mentioned above, a link could be established between the NPP's discharge and organic pollutants (TPH-GC, PAH). The analyses indicated a periodic, minor, and localized impact from the Paks NPP. Among the typical values, an outlier concentration was measured only once in both cases; no class-level change could be detected even at the discharge point, and the elevated concentration did not extend to the subsequent (<1 km) sampling section.

Even based on a detailed evaluation of the sampling sites, no significant changes attributable to discharges from the Paks NPP could be detected, nor could the impact of chemical variables be demonstrated in the community structure of biological elements. Bacteriological tests yielded similar results, which also showed no connection with discharges from the NPP.

The ecological status assessment at the water body scale indicated that the Paks NPP has no impact on the water body level, even from the perspective of biological elements. The results also confirmed that, provided current discharge conditions remain in place, no water body-level impacts related to operations are expected during the extended operation of the Paks NPP. Future changes are also expected to be largely determined by external environmental factors, particularly climate change. Accordingly, the continued operation of the Paks NPP will not jeopardize the achievement of good ecological status in the relevant section of the Danube.

Ecological analyses have also confirmed that emissions from the NPP have no detectable impact on the ecological systems of either the oxbow lakes, or the side arms examined in the affected section, and no such impact is expected during the period of continued operation. An exception to this is the operation of the alternative warm-water channel section and the connected peak cooling system, where, based on modelling results, the Uszódi-mellékág is potentially affected under certain hydrological conditions. The conditions developing in the studied side arms are shaped by other environmental and human impacts, independent of the operation of the NPP. For these reasons, the detailed impact assessment focused on the results of higher-resolution ecological analyses of the main channel of the Danube.

Based on an ecological analysis of the phytoplankton archive data and the results of the investigations, it was determined that the phytoplankton of the Danube in the studied section is not subject to any influences that would result in measurable differences in its composition. Nutrients and temperature also have only a minor effect on the structure of the community. The oligotrophic/mesotrophic nature of the river may be influenced by factors such as current light conditions, sedimentation resulting from river impoundments of the upper reaches, and a general decrease in nutrient loading. The NPP's emissions have no detectable effect on the Danube's phytoplankton communities in terms of hydrological, temperature, or chemical variables. Based on the investigations, it can be clearly concluded that phytoplankton cannot be considered an impact group.

The ecological status assessment of phytobenthos was significantly lower in the affected cross-section exposed to the warm-water discharge than in the control cross-section and in the downstream cross-sections not directly affected by the discharge. This was also evident during

the analysis of the archived data. At the same time, a more detailed analysis indicated that the community structure was primarily determined by the lower-velocity conditions developed downstream, where chemical variables may also vary at the microhabitat level. The combined occurrence of these effects creates conditions conducive to the local enrichment of limnophilic species that favor slower flow and/or higher trophic levels. The thermal gradient may amplify these local hydromorphological and chemical effects. Accordingly, the benthic diatoms can be considered an indirect receptor of thermal load in the current operational conditions, while it is a direct receptor in terms of hydromorphological effects.

Based on ecological analyses, no impact of the NPP's warmed cooling-water on the zooplankton community was detected. The environmental and biotic characteristics of the samples directly affected by the discharge do not differ significantly from those of the control sites or sites not directly affected. Based on the investigations, it can be concluded overall that the discharge of cooling-water from the Paks NPP has no detectable effect on zooplankton communities; the zooplankton community – similar to phytoplankton – is not affected.

Based on an ecological analysis of the macrozoobenthos archive data and the results of the investigations carried out in 2024 and 2025 within the framework of the study program, it can be concluded that species diversity and abundance exhibit significant spatial variation along the section of the Danube between Paks and Baja. Species counts did not indicate any trend-like changes, but the differences between the control sites and those directly affected by the warmed cooling water are statistically significant for several community structure indices. At sites affected by the discharge of warmed cooling-water, communities typically exhibit greater dominance, a more homogeneous structure, and higher abundance, while species composition shifts toward thermophilic and eutrophication-tolerant groups. The results also clearly indicate that the ecological impact of thermal load cannot be explained solely by the magnitude of the thermal gradient, but is closely related to local hydromorphological conditions. Based on temperature and flow patterns, the persistent temperature surplus is most pronounced in areas where mixing is limited, flow velocity is low, and fine-grained substrates dominate. This means that substrate conditions and the flow environment, together with thermal load, interact to shape the species composition of macroinvertebrate communities. Community restructuring therefore does not occur uniformly across sections affected by thermal load, but develops in a spatially heterogeneous manner, depending on habitat characteristics.

The supplementary investigations in 2025 confirmed the impact of thermal load on community structure, while also demonstrating that this change occurs gradually in response to rising temperatures. Changes in community structure begin to occur when there is a sustained temperature difference of $\Delta t \geq \sim 2\text{-}3°C$. This initial stage is characterized by an increase in the number of invasive species. A stable community restructuring, caused by the gradual, significant decline of native species populations, can be observed at a sustained temperature difference of $\Delta t \geq \sim 4\text{-}5°C$. During this process, the community structure shifts toward broad-tolerance, opportunistic taxa, while the relative role of more sensitive elements decreases.

The ecological status assessment confirms the results of the analyses. Warm-water discharge has a locally detectable effect on the structure of macroinvertebrate communities, which is significantly influenced by hydromorphological characteristics. Based on the analyses, it can therefore be concluded that the aquatic macroinvertebrates is a receptor biological element in terms of the NPP's discharge into the Danube.

Archival data on fishes, as well as the results of the 2024 and 2025 surveys, indicate that, among the assemblage-structure indicators, the distribution of species richness is homogeneous across the entire surveyed section of the Danube. Detectable differences arise in abundance values, with higher abundance values characteristic of the warm-water section. Based on ecological analyses, it was demonstrated that the Paks NPP's warmed cooling-water has a statistically significant impact on the structure of the fish assemblages and should therefore be considered a factor of influence. Abundance in the impact area typically increases as a result of warmer water. Warmed cooling-water and hydromorphological factors – particularly substrate composition, water velocity, and depth – collectively shape the structure of the assemblage; thus, changes in hydromorphological conditions have a more significant influence on the detectable effects of

warm-water on fish assemblages. The increase in abundance is more pronounced in areas with a more homogeneous, riprap habitats. The impact of the NPP is comparable in the riparian and medial/benthic regions. The impact of the discharge is not spatially uniform; it decreases in a gradient-like manner. The detectable impact of the thermal load also varies seasonally, and low water levels amplify the impact of the thermal load.

The supplementary investigations carried out in 2025 confirmed the earlier findings while also refining them. Based on small-scale ecological analyses, three distinguishable and ecologically meaningful ranges can be identified regarding the discharge of warmed cooling water from the Paks NPP. These threshold values are fully consistent with the values obtained from the MZB community's analysis:

- $\Delta T \approx 2\text{-}3°C$: If this range persists, the first consistent signs of community restructuring appear. The proportions of dominant taxa already differ from those observed at lower ΔT values, although the community structure still partly overlaps with them. The response is strongly dependent on substrate and flow conditions.
- $\Delta T \gtrsim 4\text{-}5°C$: If this range persists, community structure becomes markedly and stably different from sections exposed to lower thermal loading. A new equilibrium of dominance relationships develops, dominated by warm-water-tolerant, opportunistic, and in several cases strongly invasive elements. For fishes, the exact threshold determined by the analyses was 4.34, calculated as the arithmetic mean of the threshold values of all species.
- $T_{max} \geq 36°C$: In this temperature range, fishes show clear avoidance behaviour, and abundance decreases drastically in the given habitat. However, unlike the two thresholds above, this can be regarded as temporary, at least for fishes, which are substantially more mobile than the other organism groups; once the temperature decreases, recolonisation begins immediately.

Thermal load has a complex effect on biota, manifesting itself at both the individual and supra-individual levels. When assessing the thermal load of the Paks NPP, it is of paramount importance to evaluate the effects observed at the supra-individual organizational levels, as investigations over the past 25 years have never indicated any direct lethal or sublethal effects on any group of organisms. The results indicate that the impact of the NPP's thermal load should not be considered an acute lethal or sublethal effect, but rather a long-term, chronic effect. Exposure to the thermal load from the Paks NPP can be regarded as its most significant effect. This also means that, at the community level, the temperature difference is far more significant than the absolute temperature of the cooling water discharged. The most pronounced effect of thermal load is the disruption of the natural community structure, accompanied by an increase in the proportion of heat-tolerant, generalist, and disturbance-tolerant species within the community. The effect of thermal load gradually erodes the community structure, so the effect itself is gradient-like, which is not easy to demonstrate under natural conditions. It is also characteristic that the impact of thermal load occurs in conjunction with hydromorphological conditions in all affected taxa; in other words, these conditions – substrate, water velocity, and depth – significantly modify the impact of thermal load on community structure.

4.3.4.3. Impact factors, impact receptors, impacts

Water extraction by the Paks NPP via the cold-water channel, as well as the discharge of warmed cooling-water returned to the right bank of the Danube at 1526.2 rkm via the warm-water channel after use, and the discharge of treated non-radioactive process and municipal wastewater also returned via the channel, cause hydromorphological changes, an increase in water temperature, and further changes in water quality in the Danube. Based on in-depth ecological analyses of these biological elements, conducted at a fine resolution, the rise in the temperature of discharged cooling water and hydromorphological changes have a direct, detectable impact on the structure of the community. At the same time, changes in the levels of individual chemical components – based on the assessments, inorganic nitrogen forms, petroleum derivatives, and PAH – during emissions do not have a detectable impact on the ecological structure of aquatic organisms. Based on this, the following actual environmental factors and direct impacts can be identified

during current operations: (1) the hydromorphological impact of water extraction, (2) the thermal load from the discharge of warmed cooling-water, (3) the hydromorphological impact of the discharge of warmed cooling-water.

Ecological investigations have confirmed that, among the groups of organisms studied, the actual impact receptors are (1) benthic diatoms (phytobenthos), (2) aquatic macroinvertebrates (macrozoobenthos), and (3) fishes.

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 groups of organisms in the Danube is $\Delta t \geq 2.5°C$. At the same time, a significant and lasting restructuring of the community structure can be expected from a sustained temperature difference of $\Delta t \geq 4.3°C$. Based on ecological analyses, the effect of absolute temperature on fishes could also be determined. When the background temperature of the Danube is critically high, experience shows that fish tend to avoid the river when the downstream water temperature reaches $T_{max} \geq 36°C$. In accordance with thermal load models, it can be stated that the impact of thermal loads does not extend across the entire cross-section. The impact of thermal loads is typically long-term, strong, and of high significance. Thus, overall, it exerts a burdensome impact on the receptor groups within the impact area.

The hydromorphological impact of the discharged cooling water is also significant, due in part to the discharge itself and to the flow-modifying effect of the groynes constructed downstream of the discharge point. Water velocity increases at the tips of the groynes, while areas of slower flow develop behind the groynes and between them. Another cause of the hydromorphological impact is the change in habitat conditions – specifically, changes in substrate composition – related to flow velocities. The groynes have a homogeneous riprap substrate, whereas in the eddy and lower-velocity areas, a significant accumulation of smaller-grained sediment (sand/mud) can be observed. These changes have significant community-organizing effects on both benthic plants and animal organisms (phytobenthos, macrozoobenthos) as well as on fishes. Analyses have confirmed that the impacts of thermal load and hydromorphological changes reinforce each other. Consequently, this impact is fundamentally long-term, moderate, and of moderate significance in the scenarios examined. From the perspective of the impact receptors, the impact change is burdensome. In this regard, the impact of discharging the dredged sludge from the cold-water channel into the right bank of the Danube must be specifically highlighted. In this case, due to the discharge and the subsequent accumulation of finer-grained sediment in the low-velocity areas between and behind the groynes, a further alteration of habitat conditions can be predicted precisely along the downstream section and in the habitats considered critical, over a length of approximately 3 km. The impact of the warm-water discharge is expected to be significantly amplified by the discharge of dredged sludge into the Danube during the discharge period in the area on the right bank. 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 the discharge of dredged sludge into the Danube, pollutants bound to suspended solids (heavy metals) may accumulate in the filter-feeding organisms of the area. Based on the above, the discharge of dredged sludge from 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, intense, burdensome impact of major importance.

The hydromorphological impact of water extraction is less significant than that of discharge; it primarily affects the receptor organisms through changes in the riparian habitat conditions of the Danube in the vicinity of the water intake structure (riprap shore protection). The hydromorphological impact of water extraction can thus be assessed as a long-term effect in all scenarios examined, but it is weak and of low significance, and therefore, overall, has a tolerable impact for the receptor aquatic organisms.

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

The area affected by water extraction is similar in virtually every scenario – approximately 500 metres – and extends to the riparian area on the right bank between the cold-water channel and the warm-water channel, as well as to the riprap. The impact area will only increase with the commissioning of the alternative warm-water channel section, since in that case, the hydromorphological impact will extend approximately 850 metres to the new water intake point during its operation.

The hydromorphological impact area of the discharge varies only slightly across the different scenarios; its impact typically extends to the vicinity of the Large Groin.

The impact area of the thermal load varies significantly, however, depending on the scenario. The current impact area is nearly 8 km during the critical low-water condition, while during the SSLE period, it is expected to increase only slightly – by a few hundred metres – during independent operation. The scenario with the strongest impact – and thus the largest impact area – is the joint operation of the Paks NPP and Paks II NPP during the SSLE period. From the perspective of the receptor organism groups of the Danube, the maximum area of detectable impact in this scenario, based on thermal load model calculations, extends to the LQ (low water discharge) critical state of the Danube and, by the end of the operational period, covers the right bank region of the Danube up to 1508.9 rkm, to the level 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 and the peak colling system; its extent does not exceed 2 km downstream in the right-bank water bodies. The scenario with the strongest impact is the joint operation of the Paks NPP and Paks II NPP; the impact area mapped for this scenario is shown in *Figure 4.3.4.3-1.*

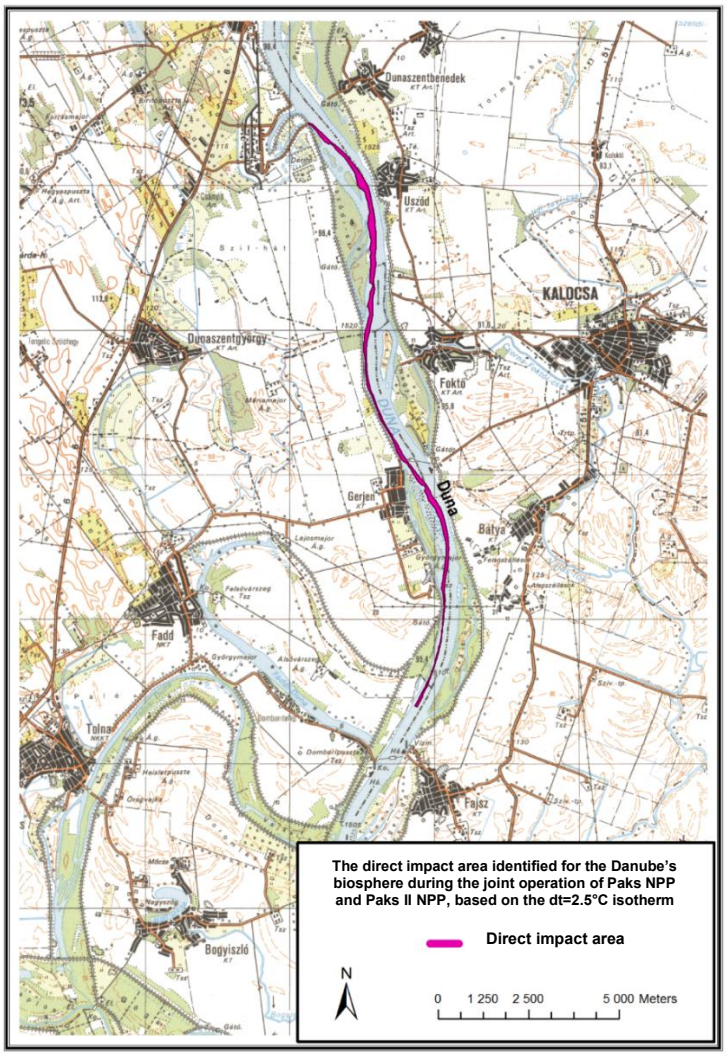


Figure 4.3.4.3-1. Maximum impact area defined in terms of Danube biosphere during the SSLE period when the Paks NPP and Paks II NPP are operating jointly

4.3.5. Assessment of emergency events

Upon examining and evaluating the emissions from the Paks NPP, the discharge of untreated wastewater into the Danube – resulting from a malfunction at the plant's wastewater treatment facility – emerges as a plausible contributing factor to an emergency event affecting surface waters.

The current treated wastewater discharge from the Paks NPP's on-site wastewater treatment plant is approximately 300 m^3/day. Among the potential emergency event scenarios, the impact of this was therefore examined, taking into account a one-day operational malfunction and calculated based on a flow rate of 300 m^3/day. The methodology for the hydrological investigations was provided by two- and three-dimensional hydrodynamic and mixing models developed within the framework of the impact assessment investigation. Actual data on the untreated wastewater entering the NPP's wastewater treatment plant were used to evaluate the chemical characteristics of the discharge resulting from the emergency event scenario under investigation.

Based on the hydrological analysis, it was determined that the mass flow rate of raw wastewater mixing with the water in the warm-water channel was 0.00347 kg/s, calculated using a normalized concentration of 1 kg/m^3. Based on this calculation, it became clear that the concentration of the chemical components in the 3.5 l/s of wastewater discharged into the warm-water channel – which has a flow rate of 100 m^3/s – is so low that, even in its untreated state, it enters the Danube at a concentration that is largely below the limit of detection.

4.3.6. Assessment of transboundary impacts

Based on the 2D thermal load model, the maximum detectable thermal excess at the Danube border cross-section during the joint operation of the Paks NPP and Paks II NPP – which was assessed as having the strongest impact – is +1.8°C under LQ Danube condition during the SSLE period.

The results of ecological analyses have confirmed that, up to a thermal excess of +1-2°C, community structure remains similar to that of the reference condition. In other words, no direct impact can be detected in the receptor groups. This finding is consistent with practical experience, as temperature differences of this magnitude can also arise from natural causes.

Detectable changes in community structure begin to occur – or become detectable – at a sustained temperature difference of between +2 and +3°C. The detection threshold determined for the receptor organisms of interest was found to be $\Delta t \geq 2.5$°C.

Based on the results of the hydrological and ecological studies, it can be clearly concluded that no transboundary impact is to be expected with respect to any biological element.

4.4. Impacts on groundwater and the geological medium

The investigation of the impact covered the environmental status of the groundwater in the Danube Valley, which lies within the broader vicinity of the Paks NPP; the geological and hydrogeological conditions of the site; and the forecasting of environmental parameters for the extended service life period. The investigation also aimed to document and assess the condition of the water bodies under investigation, analyse the environmental impacts associated with the SSLE, with particular attention to thermal loading of groundwater, and assess the physical and chemical characteristics of the water, taking into account the independent operation of the Paks NPP, as well as its joint operation with the Paks II NPP. Local and regional investigations were carried out to perform all these tasks.

4.4.1. Local assessments

Within the Paks NPP site, more detailed local investigations were conducted in accordance with Annex 4 of Government Decree 219/2004. (VII. 21.) on the protection of groundwater. The

investigation of the contamination of the geological medium within the site was based on archived data (from 2006 to 2025), while the condition of shallow groundwater was assessed using archived (from 2011 to 2024), as well as quarterly accredited groundwater sampling and laboratory test results from 2024. In addition, two types of model studies were conducted to predict the impacts:

1. A local hydrodynamic and dispersion model designed, on the one hand, to assess the impact of the existing slurry wall surrounding the planned buildings of the Paks II NPP and, on the other hand, to investigate the dispersion of potential pollutants entering the geological medium and groundwater.
2. Modelling of human health and environmental risk assessment, aimed at examining oil contaminations entering the geological medium and groundwater during an emergency event in 2024 – as a typical potential emergency event scenario.

According to Government Decree 219/2004. (VII. 21.) the assessment area belongs to the "2c" sensitivity category in terms of groundwater status; i.e., it is a sensitive area with regard to groundwater status (2.), where the top of the main porous aquifer is located within 100 m below the surface (c). The groundwater aquifer is a Pleistocene-age sand and gravel layer, with its bedrock located at a depth of 30-40 m. The upper 20-meter aquifer complex has good hydraulic parameters (permeability coefficient: $1.1 \cdot 10^{-3}$ m/s). There is a direct hydrogeological connection with the Danube riverbed, which determines groundwater movement at the regional level.

During the investigation, accredited sampling was conducted on a quarterly basis in 2024 from a total of 20 monitoring wells participating in the Paks site monitoring program. The in-situ parameters of the groundwater samples indicated that the water chemistry falls within the natural range for the area, with the groundwater being of the Na-Ca-HCO_3 and Ca-Na-HCO_3 types. The water level data collected between 2011 and 2024 are derived from observations at 111 wells monitored manually and 19 wells equipped with automatic (Dataqua) instruments. The 13-year trend indicates a decrease in groundwater levels, which becomes more pronounced as the distance from the Danube increases.

The contamination status of shallow groundwater was assessed based on the contamination limit values set forth in Joint Decree 6/2009. (IV. 14.) KvVM-EüM-FVM on limit values (contamination limit B) necessary for the protection of groundwater and the geologic medium against contamination, as well as on the measurement of contamination. The results of the accredited water sampling analysis conducted in 2024 showed that, in the case of some wells, the levels of ammonium, nitrate, molybdenum, arsenic, zinc, nickel, cobalt, and lead exceeded the applicable limit values, while no concentrations above the limit values were detected for hydrocarbon derivatives (BTEX, TPH, PAH) were not detected at concentrations above the limit values. Based on trends from 2011 to 2024, the concentrations of most contaminant components are decreasing.

Based on the monitoring results from 2011 to 2024 and the results of the accredited sampling series conducted in 2024, the areas affected by groundwater contamination have been delineated. Metal components (cobalt, arsenic, nickel, lead, zinc, copper) exceeding the (B) contamination limit are typically located in the vicinity of the industrial sludge disposal area. Most of the listed components show a steadily decreasing trend. The presence of arsenic above the limit value is due to geological origin. Nitrate and ammonium concentrations exceeding the contamination limit occur in the vicinity of industrial sludge disposal area, the sewage canal, and the make-up water treatment plant. The concentrations of the vast majority of components exceeding the contamination limit are steadily decreasing. The concentrations and extent of components exceeding the contamination limit are not significant, and their impact is tolerable.

The condition of the geological medium was assessed based on archival data sources. The investigation of the condition of the geological medium at the Paks NPP site was conducted on the basis of the environmental risk assessment 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 medium only occurred during emergency events.

The spread of any contaminants that might enter the groundwater was assessed by modelling tritium contamination resulting from technological failures 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 contaminants that may enter the geological medium or groundwater can only be smaller than this. According to monitoring data, the concentration of tritium in groundwater has decreased significantly due to the elimination of sources and the effect of the half-life. The highest previously recorded value (Well O5: approx. 10 kBq/l) is now several orders of magnitude lower, and in several wells, it is close to the natural background level (<8 Bq/l). According to the calculations of the hydrodynamic and dispersion models, the tritium lens will fall 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. Tritium activity levels vary depending on the flow conditions of the Danube. The correlation between the model and the measurements is high (0.791-0.878), which confirms the reliability of the model.

No significant contamination of groundwater or geological media is detected during normal operation. The tritium concentration shows a continuous decrease and approaches the background value. The tritium activity values vary depending on the water flow of the Danube.

Due to the anticipated interventions required to prepare for continued operation, the impacts on the geological medium will mainly result from structural disturbances (construction, embankment work, soil movement). However, these are localized and will not significantly affect the hydrogeological system. Changes in groundwater will be minimal, and no spread of contaminants is expected.

Neither the independent operation of the Paks NPP nor its joint operation with the Paks II NPP will cause any significant changes in groundwater conditions. The slurry wall and structures of Paks II NPP may locally alter flow paths, but the change is negligible at the system-wide level.

The models developed during the investigations refer to the period from 2032 to 2058. They address the flow-modifying effects of deep-foundation structures and the expansion of the cold-water channel, as well as the temporal variation in tritium load distribution. The results were categorized according to three scenarios. In a low-water environment, based on flow patterns in the vicinity of the NPP, the tritium lens decreases to below the natural background level of 8 Bq/dm^3 in approximately 1,500 days as a result of dilution, decay, and flow toward the cold-water channel. In a medium-water environment, processes slow down due to the decrease in the hydraulic gradient, and in the vicinity of the NPP, the tritium lens reaches natural levels in approximately 2,200 days. In high-water conditions, the persistent damming and backflow effects of the Danube and the cold-water channel lead to a reversal of the flow direction, which is highly unlikely under natural conditions. In this scenario, the tritium concentration would decline to natural levels over approximately 3,300 days. The results indicate a continuous, long-term decline in tritium concentration, showing that even under the most unfavourable scenario, the concentration will fall below the natural background level (8 Bq/dm^3) within 10 years. The results also suggest that, according to the investigations, flow-modifying effects caused by the Paks II NPP facilities are not detectable within the Paks NPP site.

Previous emergency events (occurring between 2006 and 2024) were typically resolved completely through rapid intervention. In the most recent incident (in 2024), the impact of the oil contamination on the environment was investigated. The human health and environmental risk assessment concluded that, in the area under investigation, indirect contact with the contaminated geological medium does not exceed the acceptable human health risk level (=1) for the exposures and contamination examined. The calculated increase in cancer risk does not reach the risk level of 10^{-5}, which is considered acceptable in the workplace. Therefore, for the receptors of the workers examined, the risk is classified as below the threshold value. It can be concluded that the emergency event under investigation does not pose a risk to human health. The contaminant under investigation migrated to another environmental medium, groundwater, but no lasting environmental damage occurred. Following remediation, no contaminants were detectable in either the geological medium or the groundwater. All of this confirms that, provided the Paks NPP's procedures are followed and the required monitoring tests are conducted, only

localized contamination within the site can occur, which can be detected in a timely manner and prevented from spreading.

4.4.2. Regional assessments

In order to assess and interpret the likely impacts of the SSLE of the Paks NPP, it was necessary to conduct a regional assessment and investigation. From a hydrogeological perspective, the bank-filtered groundwater flow system is the most sensitive to the further operation of the Paks NPP and the joint operation of the Paks NPP and Paks II NPP. Therefore, it is necessary to investigate not only the regional groundwater flow systems but also the interaction between the Danube and the groundwater. In order to do this, it was necessary to assess the variations and trends in the water stage, discharge, and temperature of the Danube, as well as the quantitative and qualitative status and pressure status of the groundwater, as well as the potentially affected operating and future drinking water resources. Subsequently, taking into account the characteristic parameters and trends necessary for conducting the impact assessment investigation, regional hydrodynamic and local heat transport models were developed, and a calibrated baseline condition was defined. The impacts were evaluated and their magnitude quantified relative to the “0” condition; i.e., compared to the baseline condition.

The investigated (model) area covers the section of the Danube between 1534 and 1498 rkm, which is essentially a lowland landscape with a gently undulating surface. Most of the area is under agricultural cultivation; on the right bank of the Danube there is a large floodplain with numerous overgrown oxbow lakes. The left-bank area has few natural watercourses and suffers from water shortages, while in the south, the Sió Canal is the only significant surface watercourse. The area was delineated based on hydrogeological criteria: the connection between the subsurface flow systems and the Danube determines the depth and extent of the investigation. From a hydrogeological perspective, the area is connected to several shallow, porous water bodies that form a contiguous regional groundwater system. The groundwater in the Danube Valley is directly connected to the higher-elevation infiltration areas of the Mezőföld, which provide a recharging source. The seepage hydraulic parameters were determined based on well lithological logs, pumping tests, covered geological maps, and data from the literature. Several shallow porous water bodies are found in the investigated area: sp.1.10.1, sp.1.10.2, sp.1.15.2. The quantitative status of several of these water bodies is poor, primarily due to water balance and FAVÖKO (Groundwater-Dependent Terrestrial Ecosystems); their chemical status is good, with the exception of the sp.1.10.1 water body, which is classified as poor (due to NO_3^-). The monitoring system covers on-site, bank-filtered, core network, and waterworks wells alike. The monitoring results are in accordance with the (B contamination) limits set forth in Joint Decree 6/2009. (IV. 14.) KvVM-EüM-FVM, as well as the limit values set forth in Government Decree 5/2023. (I. 12.) on the quality requirements for drinking water and the procedure for its control. In a few cases, limit values were exceeded (in terms of sulfate, toxicology, and bacteriology), typically due to flooding conditions. The continuous measurement data from the monitoring system do not indicate any phenomenon attributable to the NPP that would have led to a worsening of groundwater quality during the operational period. The water chemistry, microbiological, and toxicological tests reveal only natural seasonal variations. The extremely low numbers of protozoa, algae, and their skeletons found in water samples from the riverbed piezometers, as well as on-site hydrogeological measurements – primarily dissolved oxygen measurements – indicate that the natural filtration effect operating in the vicinity of the riverbed piezometers is adequate.

Within the regional model, in order to conduct an impact assessment of sufficient quality, smaller-scale, higher-resolution, and more detailed model areas were investigated, whose boundary conditions were determined based, on the one hand, on the results of the regional model and, on the other hand, on the results of the assessment of impacts on surface waters:

- vicinity of the Csámpa-puszta water resource,
- vicinity of the Gerjen-North future water resource,
- vicinity of the Kalocsa-Fadd operating drinking water resource,

– vicinity of the planned alternative warm-water channel.

The water volume abstracted in recent years (2013-2024) from the Csámpa-puszta water resource, which production originates from Upper Pannonian aquifers, showed no changes in the order of magnitude, and the operational water level corresponding to the highest production causes a maximum drawdown of 10 metres. The numerical hydrodynamic model results demonstrated that the production of the water resource does not cause a vertical flow direction change significant enough to have a substantial impact on the near-surface aquifers; thus, the operation of the Paks NPP poses no negative impact on the drinking water resource either.

Heat transport may be significant in Pleistocene-Holocene porous sediments. Based on heat transport modelling (MODFLOW-MT3DMS), it can be stated that during low water conditions, a temperature increase of up to 3°C may occur in the fine-grained sandy formation, up to 0.5°C in the gravelly formation, and an anomaly of 1-1.8°C in the layers beneath the Danube. The role of bank-filtered water intakes is significant. They can locally increase or decrease the temperature, but the impact measured in wells ranges from 0.05 to 0.3°C, which falls within the measurement limit; subsurface aquifers act as strong thermal buffers, and the thermal load gradually dissipates due to diffusion and mixing with cold water arriving from the background.

4.4.2.1. Current impact of normal operation of the NPP

The operation of the Paks NPP had no negative impact on the operation of the Csámpa-puszta water resource either during the 2013-2018 period or in 2024.

With regard to the Gerjen-North future water resource area, rather than presenting temperature variations over time, the average temperatures at the end of January and August were presented. These were referred to as indicative temperature averages, as they represent the average of the lowest and highest temperatures relative to the terrace layer. However, this average condition does not actually correspond to any single moment in time within the terrace layer due to “temperature hysteresis”, as slightly different temperature patterns develop during cooling and warming. For all calculations, the results of the temperature distribution calculations performed as part of the assessment of impacts on surface waters were used as initial conditions. Overall, the difference map between January and August clearly shows that the extent of warming is almost independent of the Danube’s temperature, and that temperatures deviating the most from the average temperature affect the area influenced by river inflow, the extent of which is still barely detectable but neutral.

In examining the impacts on the Kalocsa regional water resources, it is important to note that the thermal plume resulting from the discharge of warmed cooling-water from the NPP extends along the right bank of the Danube, while the water resources are located along the left bank. Given the high well yields, which average 2,100 m^3/d, the wells of the bank-filtered waterworks are recharged not only from the area near the left bank but also from the area beneath the thermal plume on the right bank. Due to all these factors, the temperature of the aquifer terrace layer increases more in the area below the plume than in the region of the left bank, while, as one moves toward the wells, the heat content of the incoming thermal plume is partially dissipated, and increasing mixing occurs as one approaches the wells. For these reasons, a maximum temperature increase of 0.15°C typically occurs during periods of medium discharge conditions, and 0.3-0.4°C during periods of low discharge conditions. In the space beneath the thermal plume beneath the Danube riverbed, a temperature increase of 1-1.2°C was calculated for MQ (2,300 m^3/s) and 1.5-1.8°C for LQ (910 m^3/s), an impact that is within acceptable limits.

The impact assessment of 32°C Danube water lasting 15 days on groundwater was also performed using numerical heat transport calculations. The models follow the temperature pattern presented in *Annex 3*, which contains an assessment of the impacts on surface water. In the case of the Gerjen-North water resource, the water of the plume extending along the right bank – warmed up to a temperature of 32°C – feeds the wells intended to be installed along the bank in the future. Calculations demonstrated that within the riparian zone beneath the plume, it causes a temperature increase of approximately 0.1-0.2°C, which already disappears within a few tens of metres towards the wells, becoming practically unnoticeable. In the wells, the change in water

temperature is less than 0.001°C, meaning it becomes undetectable in the calculations. For modelling reasons, the temperature increase shown was calculated based on effects lasting 4 weeks instead of 15 days; as a result, the calculated impacts are overestimated. The Foktő-Baráka water resource operates on the left bank of the Danube, while the substantial part of the thermal plume extends downstream along the right bank. In this case as well, the calculations were performed for a 4-week impact period. During the calculations, identical temperatures were obtained for maximum temperatures of 32°C and 30°C, within an accuracy of 0.001°C. Based on this, it can be stated that allowing the Danube water temperature to reach 32°C for a 15-day period has no significant impact on groundwater. If the 32°C thermal load lasts for a shorter period, the impact is also smaller. Therefore, the impact is even less than what has been presented. Due to the low infiltration rates, the impacts on the groundwater aquifer are imperceptibly small.

4.4.2.2. Impact of the operation of the alternative warm-water channel and peak cooling system

As part of the modifications planned in preparation for the SSLE of the Paks NPP, an alternative warm-water channel branching off from the existing warm-water channel and the associated peak cooling system will be constructed. The basic concept involves constructing a new section of the channel, thereby creating a new water intake point on the Danube downstream of the existing one, to the south of it. By operating the alternative warm-water channel section and the peak cooling system, it will be possible to reduce the thermal load on the Danube by lowering the temperature of the cooling water discharged from the power plant. Since the impacts increase as the Danube's discharge decreases, the variations are greatest under future LQ discharge conditions (790 m^3/s). Therefore, these cases were investigated during the heat transport modelling.

The Gerjen-North future water resource is located on the right bank of the Danube, in the vicinity of the thermal plume. According to the plans, a temperature decrease of typically 2-3°C – and up to 7°C in certain areas – will significantly alter and reduce the temperatures of the recharge from the river induced by the production wells of the water resource. For all these reasons, compared to the results presented in the baseline assessment, both the impacts on the groundwater aquifer and the water temperatures observed in the wells are significantly decreasing. Since the previous impacts were also deemed to be of a detectable magnitude but within acceptable limits, therefore, the temperature changes resulting from the operation of the alternative warm-water channel, estimated to be 55-60% of the temperature increases presented in the baseline assessment (without specific calculations for this), are also of a detectable magnitude but within acceptable limits.

The (Kalocsa) Foktő-Baráka water resource is located on the left bank of the Danube, further away from the thermal plume but still within the recharge zone of the wells. Therefore, the presented temperature decrease – typically 2-3°C, but reaching up to 7°C in certain areas – also alters and reduces the temperatures of the recharge from the river induced by the production wells of the water resource to a lesser extent. Due to all these factors, compared to those presented in the baseline assessment, both the impacts on the groundwater aquifer and the water temperatures appearing in the wells decrease slightly. Since the previous impacts were also judged to be of a detectable but acceptable magnitude, the temperature changes occurring during the operation of the alternative warm-water channel – representing an estimated 90% of (i.e., decreasing by 10% compared to) the temperature increases presented in the baseline assessment, without separate calculations performed for this case – are also of a detectable but acceptable magnitude.

The evolution of temperature was calculated using a heat transport model in the vicinity of the existing and alternative warm-water channel sections, which demonstrated that while a detectable annual average temperature increase of only a few tenths of a °C is probable directly beneath the channels, its impact on the terrace layer is already negligible (around a maximum of 0.1-0.15°C). Overall, the impacts can be considered neutral, even under multiply conservative assumptions.

4.4.2.3. Impacts of the SSLE

The current conditions surrounding the operation of the Paks NPP will not result in any changes to the operation of the Csámpa water resources due to the extension of the plant's service life. The conditions described during the baseline assessment (2024 conditions) will persist. The modelling calculations proved that the zone of depression developing around the wells of the water resource does not reach the surface. Therefore, the aquifers storing the drinking water are not endangered by surface contamination. Contamination from the site cannot reach the wells of the Csámpa-puszta water resource because:

- the impact of the increased production has no surface intersection,
- the recharge area does not point towards the power plant site; on the contrary, the water flows towards the wells of the water resource from the west-northwest.

The conditions existing under the current operation of the Paks NPP will cause no change regarding the impacts on the Gerjen-North future water resource due to the SSLE. The calculations were performed for a total period of 30 years – which is sufficiently long – in order to allow a near-equilibrium state to develop between the infiltrating zone of higher temperature and the zone of lower temperature located in the terrace layer. Since the Gerjen-North area is the region most exposed to the impacts, the heat transport calculations reached a quasi-steady state, and the investigated LQ=790 m^3/s case represents the situation with the greatest thermal impact, it can be stated that the temperature impacts on the waterworks wells cannot be greater than the scenario presented here, partly due to higher discharges and partly due to lower thermal loads. The fact that the differences in the variations of the temperature patterns (differences of the differences) had to be investigated to establish trend-like deviations indicates that the impacts in absolute terms – although detectable – are small; their differences during the investigated cases are practically identical in terms of both pattern and magnitude, as also demonstrated by the fact that the two cases (the operation of the Paks NPP, and the joint operation of the Paks NPP and Paks II NPP, with dT=11°C under future Danube LQ discharge conditions) resulted in entering water temperatures falling into a similar range for the wells.

The wells of the Foktő-Baráka water resource, however, are located on the left bank; nevertheless, due to the high production of certain wells – even exceeding 2000 m^3/d – they receive recharge not only from the left bankside zone but also from areas beyond the thalweg. Consequently, the plume on the right bank, which has an elevated temperature due to the operation of Paks II, also contributes to the recharge of the wells' water. All this causes a temperature increase both in the terrace layer and in the vicinity of the wells. The extent of the impacts on the terrace layer was calculated using the temperature distribution specified for future Danube MQ and LQ discharges for the productions of Paks II NPP and the Paks NPP, as presented in *Annex* 3 on the impacts on surface waters. Under a Danube discharge condition of LQ = 790 m^3/s, the maximum temperature increase is 1-1.5°C in the riverbed sediment beneath the plume, while it ranges between 0.1°C and 0.4°C in the left-bank near-shore zone (*Figure 4.4.2.3-1.*). In the area of the wells, the impact of temperature increases dropped below 0.1-0.05°C. Overall, it can be established that the commissioning of Paks II NPP has no impact either on the left-bank water production or on the bank-filtered water resources located in the left-bank zone.

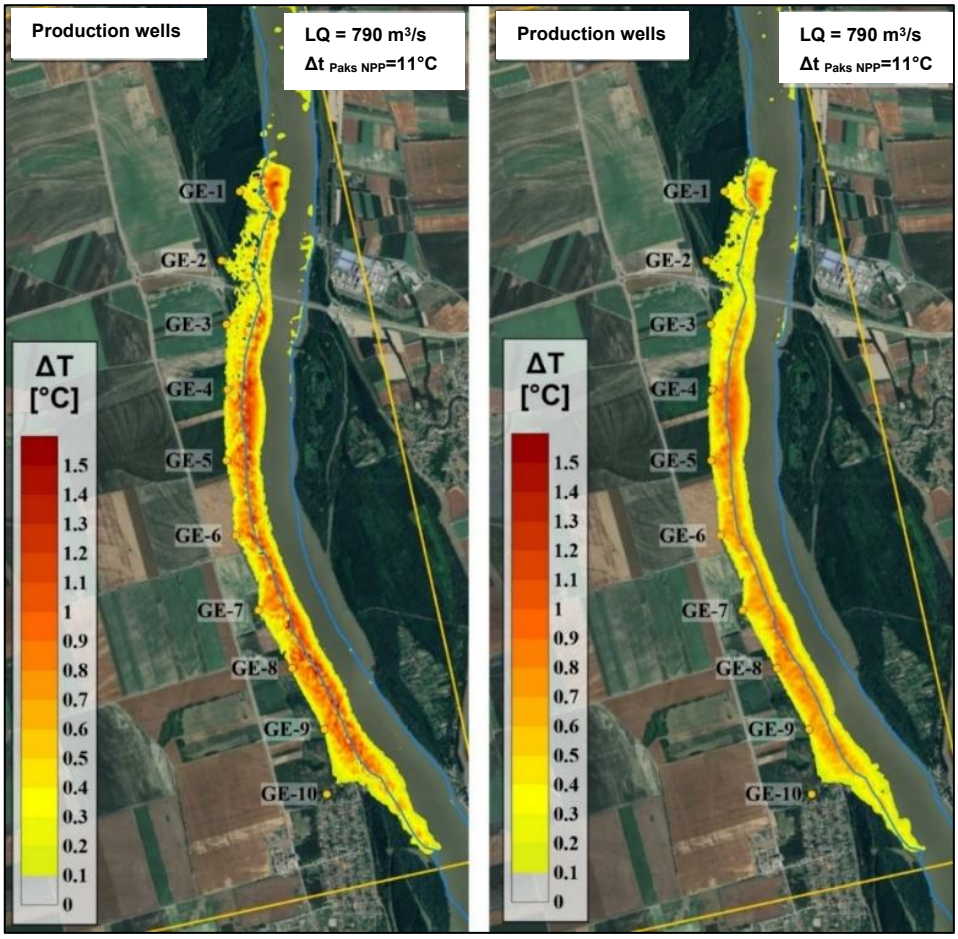


Figure 4.4.2.3-1. Temperature change caused by the thermal load of Paks II NPP in the upper and lower zones of the aquifer at the end of the warmest period (31 August) under the discharge Condition of LQ = 790 m³/s

Overall, regarding the thermal impact of the joint operation of the Paks NPP and Paks II NPP on the groundwater, it can be established that the impacts are negligible even under multiply conservative assumptions. It can also be seen that the impacts of individual warm-water channels and channel sections are detectable directly beneath the surface, limited solely to the area of the currently operating channel section, with a small-scale temperature increase effect below 0.5°C, but typically below 0.3°C (*Figure 4.4.2.3-2.*).

In the terrace layer, this impact decreases further; thus, although the superposition and accumulation of these impacts can be observed, this summation occurs at such low temperatures – around a maximum of 0.2°C – that the resulting accumulated impact can also be considered negligible. All this also implies that the individual warm-water channels have separate areas of influence, meaning that the impacts can be determined both individually and jointly through simple summation.

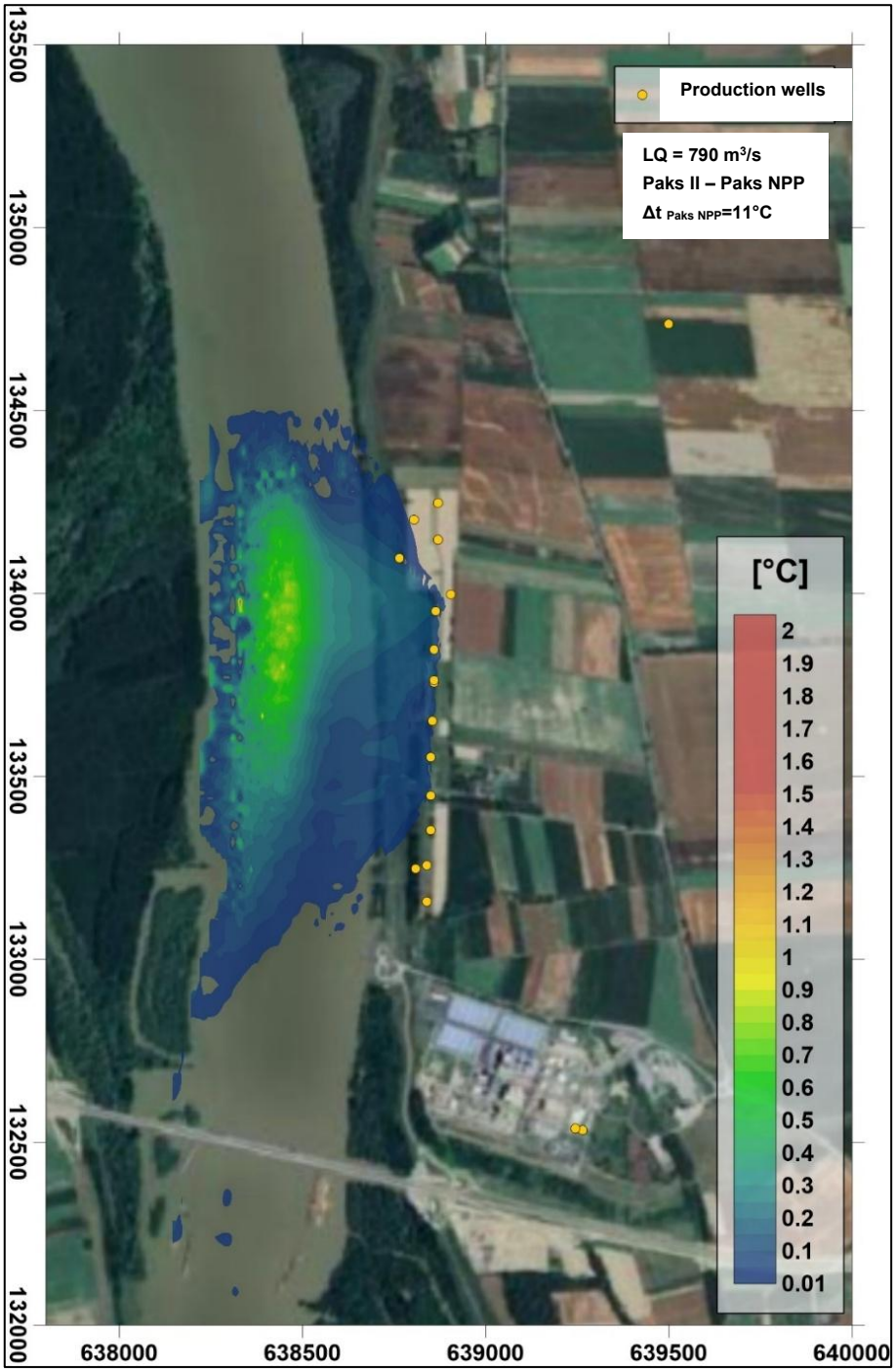


Figure 4.4.2.3-2. Temperature-increasing effect of the excess thermal loads developing following the operation of Paks II NPP on the area and wells of the Foktő-Baráka water resource under the discharge condition of MQ = 2300 m³/s

4.5. Impacts on biosphere and ecosystems

With regard to biosphere and the ecosystem, the investigation focused on the current operation of the NPP units to date, as well as the nature and extent of the impact that the combination of factors related to their operation in recent years has had on the biosphere as an environmental medium, and the areas affected by these impact factors. In addition, based on the results and conclusions of the environmental impact assessment covering the recent period, an objective assessment was conducted of the expected impacts on biosphere and the ecosystems within the impact area during the SSLE of the Paks NPP.

The impact assessment is based, on the one hand, on the results of current biomonitoring feasibility studies – which serve as the foundation for this environmental impact assessment – as well as on data and information available from surveys conducted during earlier periods of operation at the Paks NPP.

No detailed investigation results regarding biosphere are available for the period immediately preceding the construction of the Paks NPP (late 1970s, early 1980s). Thus, the site characterization program (2001-2004) related to the environmental and water rights licensing of the previous service life extension and capacity increase of the Paks NPP, as well as the results of the exemplary biomonitoring studies (2011-2012) that served as the basis for the EIA required for the environmental licensing of the new NPP units (Paks II NPP). These results could be relied upon as definitive indicators of the previous condition of the biological communities within the impact area.

The basic concept of the investigation was to compare data by biological group, involving a comparative analysis of the results from the earlier surveys (2001-2004 and 2011-2012) with the current survey results (2024-2025).

Conclusions regarding this matter were drawn primarily from the results of the comparative analysis of the previous and current conditions (assessment of changes in condition) and from the content of the impact assessment chapters in the documentation prepared for the two periods, to determine the nature and magnitude of the impacts expected on biosphere and the biological communities within the impact area during the period of the SSLE. During the impact assessment, the expected impacts were evaluated separately for the scenario in which the Paks NPP and Paks II NPP operate jointly, as the potential impacts could be cumulative in that case. The impacts of emergency events were assessed separately, as were transboundary environmental impacts that have a measurable, significant probability of occurring.

In its opinion concluding the preliminary consultation, the environmental protection authority requested the development of a nature conservation action plan in the event that continued operation were to result in drastic changes to the biosphere in the immediate impact area (e.g., fish mortality in the Danube). The preparation of a nature conservation action plan is warranted if, as a result of significant adverse effects associated with the operation of the power plant, substantial destruction or degradation is observed in a species or habitat of conservation importance. No such incident has occurred to date in connection with the operation of the NPP. No changes are expected in the plant's environmental emissions during the SSLE period. Therefore, no extraordinary events – which cannot be addressed through the application of existing regulations – are likely to arise in the future that would necessitate the development of a nature conservation action plan.

4.5.1. Assessment area and period

The area covered by the investigations was a 10-kilometre radius circle centred on the NPP site. Within this area, the assessment area was divided into two parts; more detailed biological surveys were conducted within a 3-km radius around the site, as, based on previous studies, the impact range for most impact factors associated with the plant's operation that could potentially affect biosphere is 3 km or less. 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 within that area. The main objective of the data collection was to lay the groundwork for preparing the Natura 2000 impact assessment documentation relevant to the Tolnai Duna Natura 2000 site located within the potential biosphere protection impact area (10-km radius). The delineation of the assessment area is illustrated in *Figure 4.5.1-1*.

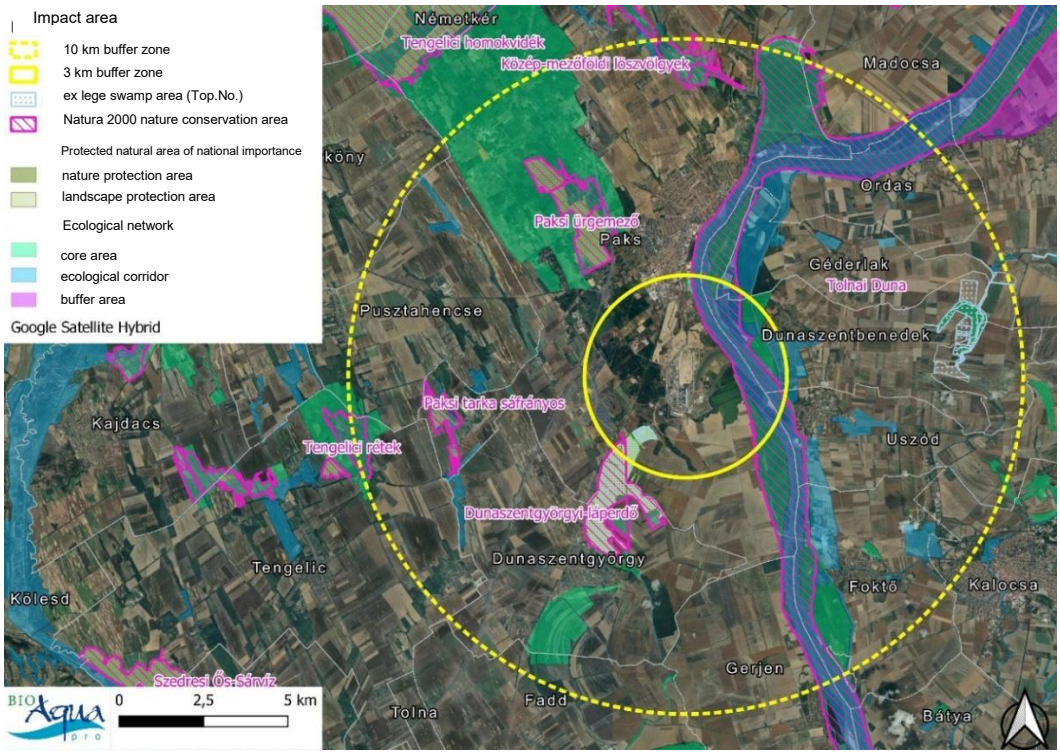


Figure 4.5.1-1. The 3-km and 10-km zones around the NPP site that can be defined as the assessment area, as well as the nature protection areas located within the affected area
(Natura 2000 sites, protected natural areas of national importance, ex lege areas, and areas belonging to the National Ecological Network)

With regard to the assessment area described above, the field biological surveys listed in *Table 4.5.1-1* were conducted as part of the series of feasibility investigations forming the basis of the EIA. The surveys took place between May 2024 and March 2025.

Table 4.5.1-1. Biotic groups surveyed in the assessment area

Investigated group	Investigations carried out within a 3-kilometre radius	Investigations carried out within a 10-kilometre radius
Botanical investigations (creation of an Á-NÉR map)	X	–
Botanical investigations (survey of protected plant species)	X	–
Botanical investigations (survey of indicator plant species and habitats)	–	X
Macroscopic aquatic invertebrates	X	X
Dragonflies and macroscopic aquatic invertebrates of conservation importance	X	X
Fishes	X	X
Orthoptera	X	X
Butterflies	X	X
Ground-dwelling arthropods	X	–
Saproxylic beetles	–	X
Amphibians and reptiles	X	X
Birds	X	–
Bats	X	X
Other mammals	X	X

4.5.2. Summary assessment of the environmental conditions prior to the SSLE

The baseline status of the biosphere as an environmental medium prior to the SSLE of the NPP was presented in *Annex 6* through the results of the investigated organism groups. A detailed analysis of both terrestrial and aquatic ecological communities was conducted. A comparison of surveys from previous years with those from 2024-2025 shows that, in terms of biosphere – when comparing terrestrial biosphere with aquatic biosphere – the Danube ecosystem is the most significant receptor. For this reason, this chapter provides a summary assessment of aquatic biosphere specifically.

The investigation of aquatic biosphere also covered aquatic macroinvertebrates and fish communities. Within the aquatic macroinvertebrate community, the investigation covered 12 major groups of organisms. Species-level investigations were conducted on aquatic snails, bivalves, leeches, malacostracans, mayflies, dragonflies, aquatic and semiaquatic bugs, and stoneflies, aquatic beetles, and caddisflies, as well as studies of oligochaetes and dipterans at the higher taxonomic category level.

The number of taxa identified in all samples does not differ between sampling points upstream and downstream of the NPP, and is characteristic of nearly the entire length of the Hungarian section of the Danube. More than half of the identified taxa are non-native. The proportion of individuals belonging to non-native taxa ranges from 62% to 97% in individual samples, and 94% across all samples, meaning that the majority of the detected individuals belong to non-native taxa. This pattern is characteristic of nearly the entire Hungarian section of the Danube; the reason is the exceptionally high density of invasive snail and malacostracan species – no native species from the latter group were detected at all during the investigations.

Recent surveys of the Paks section of the Danube have confirmed the presence of a total of 42 fish species. Of these, 2 are strictly protected, 6 are protected, and 8 are of community importance (Natura 2000). At the same time, 10 non-native and invasive species are also present, representing 25.6% of the species and 23.8% of the total number of individuals. The results reflect the species composition typical of fish communities in the lower section of the Danube in Hungary; the fish assemblage holds significant ecological and conservation value.

4.5.3. Current impacts of the NPP and expected changes resulting from the SSLE

4.5.3.1. Methodological approach to the delineation of the actual areas of influence for the protection of biosphere

The requirements set forth in Annex 7 of Government Decree 314/2005. (XII. 25.) were applied in delineating the area of impact on biosphere. The delineation was based on the identification of specific impact factors potentially affecting biosphere, the determination of their spatial extent, their mechanisms of action, their temporal characteristics, as well as the sensitivity and ecological characteristics of the potentially affected receptor organism groups.

4.5.3.2. Impact area for the protection of biosphere during the construction work performed as part of the preparations for the SSLE

Construction activities involving significant environmental impacts will occur in connection with the preparation of the SSLE of the Paks NPP and its subsequent operation, during the construction of the alternative warm-water channel section and its connected peak cooling system, as well as other related facilities (e.g., structures, pipelines, electrical equipment).

From the perspective of biosphere, the indirect impact area of the construction phase (*Figure 4.5.4.2-1.*) includes those areas where the impacts of construction work are not felt directly in a physical sense (e.g., land occupation), but indirectly, through their impact on other environmental medium (e.g., air, groundwater or surface water), thereby influencing the life processes and behaviour of a component of the biosphere (individuals and populations of species comprising the biosphere), and consequently affecting the evolution of the species' population in the given area (e.g., reproduction rate, and through this, population size).

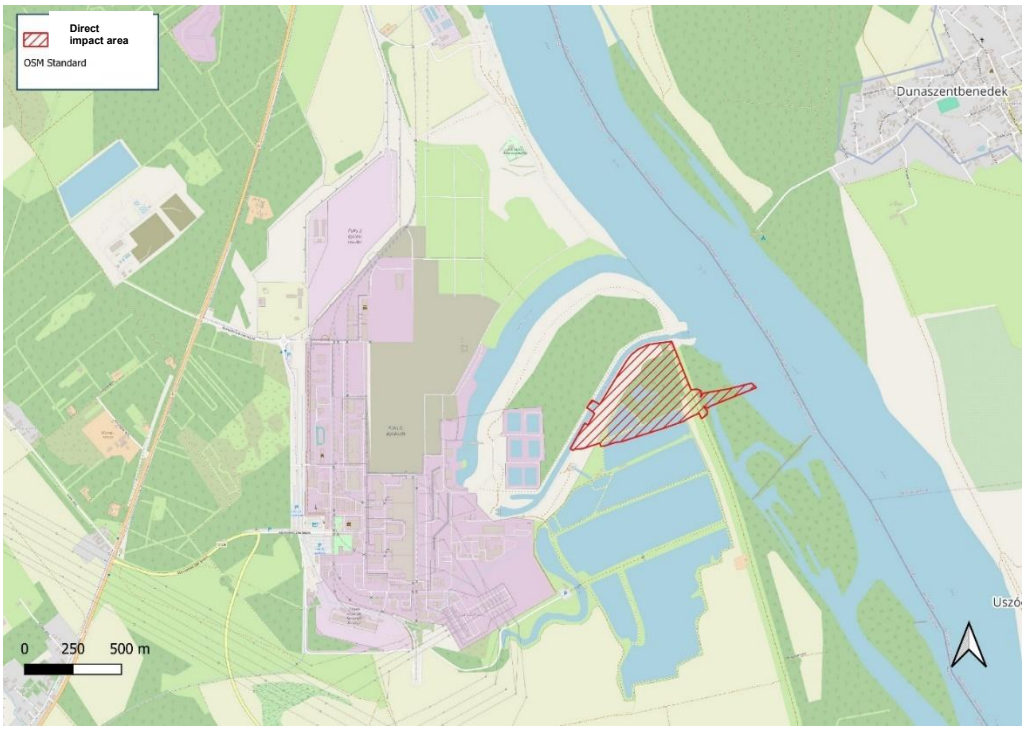


Figure 4.5.4.2-1. Direct impact area on biosphere protection resulting from construction work on the alternative warm-water channel and peak cooling system

Assessing the expected indirect impacts on biosphere is a complex issue, as individual species exhibit varying degrees of sensitivity to different environmental impacts. Most of the practical experience that can actually be applied relates to vertebrates, and within that group, primarily to birds.

According to available ornithological survey data, the species found nesting in the area most directly affected by the construction work for the planned alternative warm-water channel and peak cooling system – that is, the area of direct impact on biosphere protection – are the Red Kite (*Milvus milvus*), the Black Kite (*Milvus migrans*), and the White-tailed eagle (*Haliaetus albicilla*), which are more sensitive to acoustic and visual disturbances than other species nesting in the survey area. Based on our current knowledge, among the species found in the area, the White-tailed eagle is considered by expert consensus to be the most sensitive to acoustic and visual disturbances caused by human activity. Therefore, information regarding this species must be used as the basis for determining the indirect impact area (*Figure 4.5.4.2-2.*).

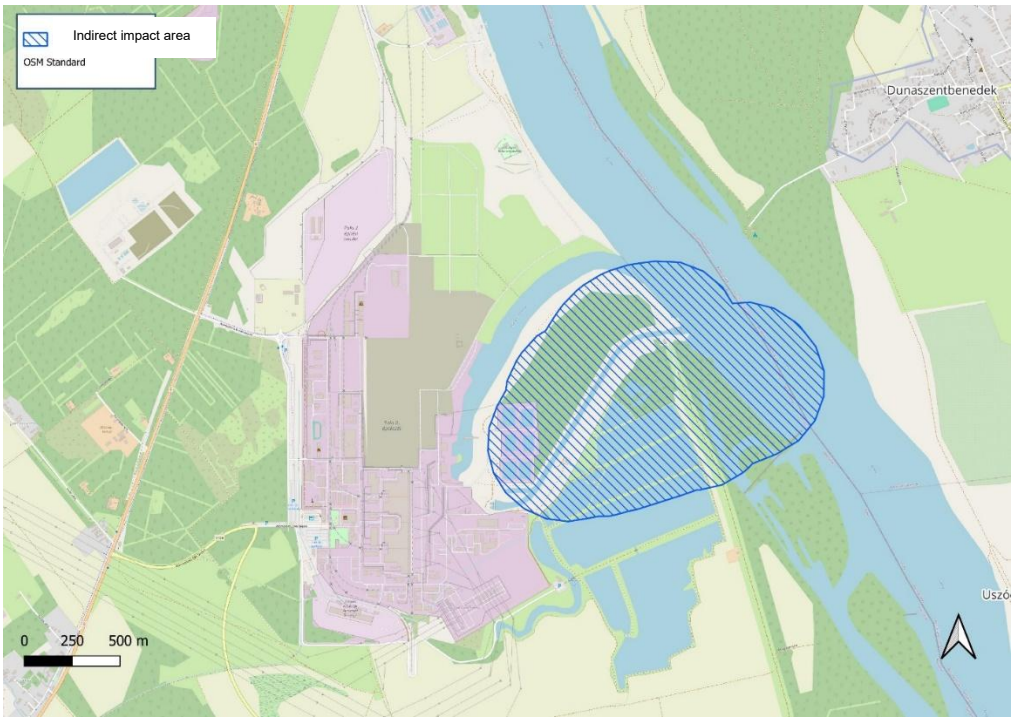


Figure 4.5.4.2-2. Indirect impact area on biosphere protection of construction work for the alternative warm-water channel and peak cooling system

4.5.3.3. Impact of operation on biosphere protection during the period of the SSLE

From the perspective of biosphere protection, the operational impact area must include the areas where impact factors associated with the normal operation of the NPP – and which have the potential to affect the biosphere – occur, provided that the impact assessment detects even a minor quantifiable impact or that such an impact can be inferred from data in the literature. These factors also define the impact area during the SSLE period.

Furthermore, the area affected by the operation includes all areas where the planned new facilities, in this case the planned 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 biocoenosis compared to the current baseline condition.

Overall, the extent of the cumulative impact area calculated based on the impact areas associated with the above impact factors is shown in *Figure 4.5.4.3-1*. (A detailed analysis of the impacts of thermal loading on the Danube is provided in *Chapter 4.3.* and *Annex 3*. Therefore, the impact area figure depicts only the impact area of effects on terrestrial biosphere.)

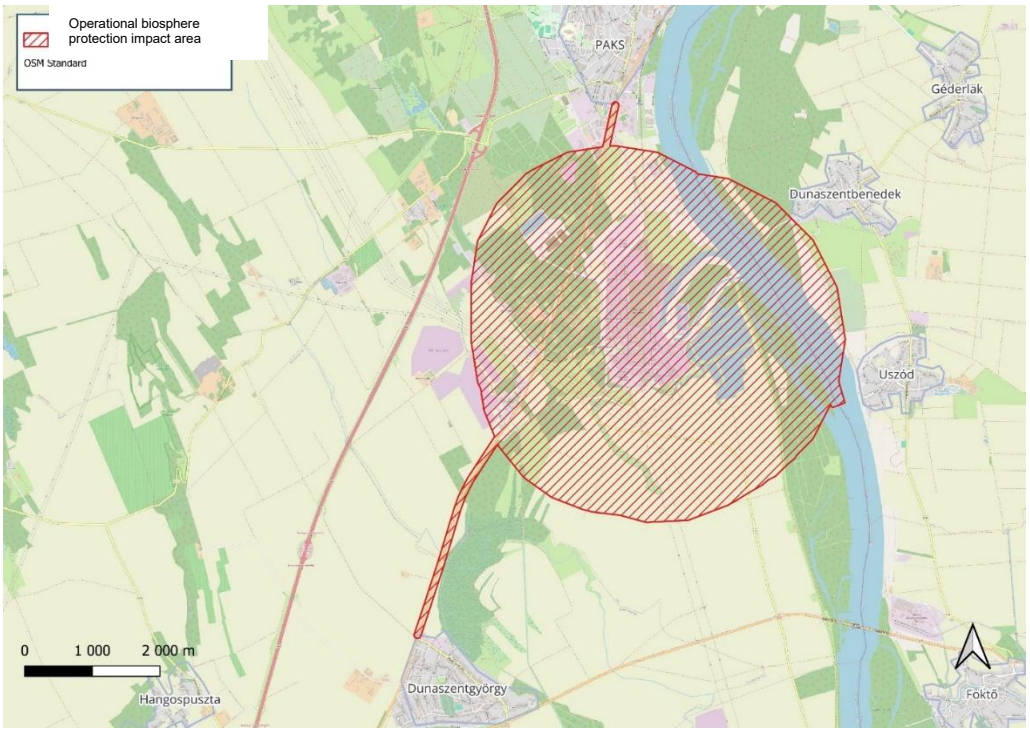


Figure 4.5.4.3-1. Impact area of the operation of the NPP on biosphere protection during the period of the SSLE

4.5.3.4. Impact of normal operation during the previous operating period of the Paks NPP

The following impact factors associated with the normal operation of the NPP have been identified as having the potential to affect biosphere as an environmental medium:

1. Land occupation and land use during the previous operating period – did not result in any changes in volume or land use.
2. Transportation (operating personnel, delivery of operating supplies, tools, machinery, and equipment, and removal of waste, which involves air pollution, noise, vibration, and disruption).
3. Technological water extraction from the Danube (changes in surface water volume).
4. Extraction of drinking water from the Csámpa waterworks (changes in groundwater levels).
5. Discharge of warmed cooling water into the Danube (thermal load, changes in water quality due to technological wastewater).
6. Generation and treatment of wastewater and stormwater (quantitative and qualitative changes).
7. Generation, on-site storage, transport, and management of waste (conventional and radioactive).
8. Light pollution caused by the nighttime lighting of the NPP site.
9. Operation – all other loads, pollution, and emissions (noise impact, visual disturbances resulting from human presence or activities, etc.).
10. The effects resulting from the operation of overhead power lines (collisions, injuries caused by electric shock, deaths, and the electric field).

The assessment of the impacts of normal operations during the Paks NPP's most recent operating period on biosphere was conducted methodologically by comparing the current investigation results from 2024-2025 with the results of investigations conducted in 2001-2004 and 2011-2012, and, due to the availability of data from regular monitoring investigations on the Danube's biosphere, the comparison could be extended all the way up to the status as of 2021. Based on

the results of comparative analyses conducted separately for each group of organisms examined, it was determined whether any differences exist between the previous state and the current state as determined by the 2024-2025 surveys. In the next step, the detected differences were evaluated to determine whether they can be linked to the impact factors identified in connection with normal operation during the NPP's previous operating period and which, based on literature data and our own experience, were preliminarily identified as impact factors potentially affecting biosphere.

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

Based on the assessment, it can be concluded that, among the impact factors identified in connection with the normal operation of the NPP and listed above that could potentially affect biosphere, factors 1, 2, 3, 4, 6, 7, and 9, no detectable or assessable impacts can be identified for any of the examined groups of organisms. Therefore, these factors are neutral for all examined groups of organisms.

For impact factors No. 8 (light pollution resulting from nighttime outdoor lighting at the NPP site) and No. 10 (impacts resulting from the operation of overhead power lines), a perceptible, quantifiable negative impact can be identified. However, the extent of the impact is only minor and tolerable for these impact factors as well, based on the categorization according to the impact assessment system used). In the case of impact factor 5 (discharge of warmed cooling water into the Danube), a significant, adverse impact can be identified.

The discharge of cooling water into the Danube is a relevant factor for aquatic macroinvertebrates and fish communities; the Danube's biotic community is a key recipient of these impacts. No trend-like change in species numbers was detected for aquatic macroscopic invertebrates, but differences between the control sampling sites and those directly affected by the warmed cooling-water were statistically significant for several community indices.

In areas affected by the discharge of warmed cooling water, communities typically exhibit greater dominance, a more homogeneous structure, and higher abundance, while species composition shifts toward heat-tolerant and eutrophication-tolerant groups. The results also indicated that the ecological impact of thermal loading cannot be explained solely by the magnitude of the Danube's thermal gradient, but is closely related to local hydromorphological conditions. The impact of the discharge is stronger in habitats where flow velocity is low and fine-grained substrates dominate.

In the case of fish, the results of ecological analyses confirm that in the areas affected by the discharge – both in the right-bank riparian (shoreline) and right-bank medial (open-water) regions of the Danube – the elevated water temperature resulting from the discharge is a significant environmental factor shaping the fish assemblage, and has a significant impact on the structure of the fish assemblage. No differences were observed in species composition. However, an increase in the number of individuals per unit length (abundance) was observed in the parts of the riverbed most exposed to thermal load. Based on the results of the analysis, measurable, detectable impacts on the aforementioned receptor organism groups are observed at distances of 800-1,000 m from the discharge point.

Ecological analyses of the fish assemblage demonstrated that the warmed cooling water from the Paks NPP has a statistically significant impact on the structure of the fish assemblage. Within the impact area, fish abundance typically increases as a result of the warmed water. The warmed cooling water and hydromorphological factors – particularly substrate composition, water velocity, and depth – collectively shape the structure of the community. Thus, changes in hydromorphological conditions significantly influence the detectable impact of warm-water on fish communities. The increase in abundance is more pronounced in areas with more homogeneous, riprap substrates. The impact of the Paks NPP is comparable in the riparian and medial regions. The effect of the discharge is not spatially uniform; it decreases in a gradient-like manner. The observable impact of thermal loading also varies seasonally, and low water levels amplify its effects.

Light pollution from the Paks NPP is a relevant factor for butterfly, bird, and bat populations. In the case of butterflies, based on field observations and data analyses, the observed differences cannot be attributed primarily to the impact of light pollution, as the differences observed during sampling in habitats with varying structures are primarily explained by differing environmental conditions (e.g., vegetation composition and structure), which in all likelihood mask the impact of light pollution, which is in any case much smaller in magnitude. However, based on the relevant literature, minor adverse impacts can be expected, primarily because moths – especially nocturnal species – fly toward strong nighttime light sources (positive phototaxis), meaning they are attracted to artificial nighttime light sources. This minor adverse impact is within acceptable limit. In the case of the bird community, the estimated effects of light pollution cannot be considered significant; the extent of the impacting factor – that is, the direct impact of light pollution from the Paks NPP – is largely local due to its limited scope. In the case of bats, the light pollution present in the vicinity of the NPP does not cause the complete disappearance of the bat fauna, but results in a spatial redistribution of species composition and activity, which primarily adversely affects light-aversive species associated with closed habitats. The sighting frequency of these species is lower at the power plant site – which is characterized by significant light pollution – and in its immediate vicinity than further away. The adverse impact on the region's bat communities is tolerable.

The impacts resulting from the operation of overhead power lines are relevant factors for the bird community. At the same time, with regard to this group of organisms, it can be concluded that the impacts on the nesting and foraging bird community in the investigation area are not significant in terms of "injuries and mortality caused by collisions with overhead power lines and electric shock", and "the effect of the electric field of overhead power lines" were not conspicuous; consequently, there is no significant negative impact resulting from the power plant's operation, and its impact is tolerable.

4.5.3.5. Expected impact of preparations for the SSLE

In connection with the preparation of the SSLE, the following impact factors – typically related to construction activities – have been identified as having the potential to affect biosphere as an environmental medium:

1. The land occupation required for the construction of the alternative warm-water channel section and the associated pumping station, as well as the cooling cells of the peak cooling system and other related facilities, and the use of work areas associated with the construction processes, which have direct physical impacts.
2. The impact factors causing the indirect effects of the construction work on the alternative warm-water channel section and the associated pumping station, as well as on the cooling cells of the peak cooling system and other related facilities, including air pollutant releases resulting from construction processes, noise emissions, and visual disturbances caused by the presence and movement of construction personnel and machinery.

Based on the assessment, it can be concluded that, with regard to the impact factors listed above – which were identified in connection with the preparation of the SSLE and which could potentially affect biosphere – no significant negative impacts were detected for any of the investigated groups of organisms. Although the interventions locally affect habitats located in the area affected by the land use of the planned facilities and the use of the work area required for construction, taking into account the population segments of the investigated organism groups associated with these habitats, as well as the condition, extent, and species composition of the affected habitats, the expected impacts are tolerable for all investigated organism groups. This can be justified by the fact that they do not induce lasting, irreversible changes in the populations of the receptor species living in the region.

The route of the planned alternative warm-water channel section also affect the southern shelter area designated in connection with the Paks II NPP construction works. The protected animals were relocated to this area from the area between the cold- and warm-water channels ("island"). Several types of dens have been placed in the designated refuge area since 2019. In the first

year, type B bird nests and bat nests were installed, and from 2020, type D nests, owl boxes, and kestrel nest boxes were also installed. Since the refuge area falls within the construction area of the alternative warm-water channel and will be destroyed in this form, a new refuge area will be designated that is located near the original, has a similar size and similar habitat characteristics. At least the same number of den types and box types as originally installed will be placed in the new refuge area.

4.5.3.6. Expected impacts of the SSLE

Independent operation of the Paks NPP

For the SSLE period as well, the impact factors that could potentially affect biosphere as an environmental medium have been identified. The impact factors for the SSLE period are essentially the same as the 10 factors previously identified as characteristic of the NPP's past operating period, both when the Paks NPP operates independently and when it operates jointly 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 – planned for the period of joint operation – and the associated facilities (thermal load, changes in water quality due to technological wastewater) does not constitute a new environmental impact factor. However, with the establishment of the new Danube discharge point, this impact factor will occur at the new discharge point.

During the SSLE period, if the Paks NPP operates independently, the magnitude of the impact of the factors examined and the level of environmental impact are expected to be exactly the same as those characteristic of the previous operating period. The only expected difference is that the warmed cooling water will typically be discharged into the main channel of the Danube either via the current warm-water channel or the new alternative warm-water channel, but the volume of cooling water and the level of thermal load will remain at most the same. Consequently, the impacts on biosphere – as an environmental medium – and, more specifically, on the examined groups of organisms will be virtually identical to those detected during the previous operating period, both in terms of the nature and extent of the impacts.

It is expected that during the SSLE period as well, groups of aquatic macroscopic invertebrates and fish will be the communities most significantly affected by operations, similar to the previous operating period. In terms of the impacts on these groups of organisms, the actual driving impact factor is the discharge of warmed cooling water into the Danube. If the cooling water is discharged via the current warm-water channel, then the nature, intensity, and extent of the impacts will be identical to those observed during the previous operating period. If the warmed cooling water is discharged through the alternative warm-water channel section, then the nature and intensity of the expected impacts will, in the worst-case scenario (assuming the peak cooling system is not operational), likely be the same as the current situation, but the area of impact will be shifted 400 m downstream, and the impact area will extend from the Danube confluence of the alternative channel section to the 800-1,000 m section of the Danube's right-bank riparian (shoreline) as well as the right-bank medial (open-water) region, where measurable adverse deviations are expected. At the same time, however, unlike previous ones, the new discharge point also affects the hydrodynamic conditions of the Danube, thereby altering the efficiency of mixing. It should also be noted that, as a result of the operation of the peak cooling system to be installed alongside the alternative warm-water channel section, the thermal gradient of the Paks NPP in the Danube will decrease compared to previous operational conditions, thereby mitigating the negative impact on biosphere.

Joint operation of the Paks NPP and the Paks II NPP

During the SSLE period, in the event of the joint operation of the Paks NPP and the Paks II NPP, all impact factors that could potentially affect biosphere as an environmental medium are identical to the impact factors already described in connection with the expected independent normal operation of the Paks NPP during the next operating period. However, the same contributing impact factors exist in the case of the parallel operation of the two NPPs, arising from the

operation of both facilities. Therefore, the impacts caused by these factors are cumulative. In this case as well, groups of aquatic macroscopic invertebrates and fish can be considered the communities where the cumulative effects are most likely to cause noticeable, measurable changes. Based on the analyses, provided that the restrictions on the thermal load on the Danube specified in the regulatory licences are complied with during the joint operation of the Paks NPP and Paks II NPP (temperature limit of 30°C at a distance of 500 m from the discharge point), no deterioration in the ecological status of the water body is expected, as indicated by the status assessment based on aquatic macroinvertebrates and the fish assemblage. At the same time, the spatial extent of the adverse impact downstream increases from 8 km to 17 km. A detailed analysis of the effects of thermal loading is provided in *Annex 3*.

The impact resulting from the joint operation of the two NPPs is expected to be mitigated during critical periods by the new alternative warm-water channel section and peak cooling system planned for the Paks NPP, as well as by the operation of a similar peak cooling system planned for the Paks II NPP.

4.5.3.7. Impacts of emergency events

In assessing the impacts of emergency events on biosphere and ecosystems, only those types of emergency events were considered for which there is an assessable, significant probability of occurrence. These are typically emergency events with a small impact area and local impacts.

Among these emergency events, incidents such as “the release of hazardous substances into the soil, or a hydrazine pipeline leak in the courtyard” can have a direct toxic effect on higher plants, orthoptera, and butterflies, ground-dwelling arthropods, and amphibians. The impact area of the adverse direct impact is essentially limited to the site of the Paks NPP and, through leakage, at most its immediate environment. In the event of such an emergency event, indirect toxic impacts on birds, bats, and certain other mammal species – primarily those occurring on the site, or in its immediate vicinity – cannot be ruled out via the food chain. In these cases, the damaging impact may occur when they consume food organisms that have already been exposed to direct or indirect toxic effects and have either died or are still alive but already contain toxic substances in their bodies.

In the event of an emergency event of the type “water pollution via the warm-water channel”, pollutants may enter the receiving Danube via the warm-water channel; thus, the receptor organisms are primarily the species communities that make up the aquatic ecosystem of the Danube. The directly affected receptors include macroscopic aquatic invertebrates, fish, amphibians, water-dependent reptiles, and water-dependent mammals (e.g., otters and beavers). Depending on the nature of the pollutant involved, the expected impacts may include various toxic impacts. In the event of this emergency event, indirect toxic impacts via the food chain cannot be ruled out; these may occur through the consumption of organisms exposed to direct or indirect poisoning. Such indirect receptors may include aquatic and water-dependent foraging birds, as well as certain other mammal species that are regularly occurring along the banks of the Danube and that feed on aquatic organisms at least occasionally. The immediate impact area of this type of emergency event is typically the right-bank riparian and medial sections of the Danube downstream of the warm-water channel outlet, and the extent of its downstream spread depends on the toxicity and degradation characteristics of the toxic substance, as well as the duration of the discharge of the toxic substance itself.

The current discharge of treated wastewater from the Paks NPP’s on-site wastewater treatment plant is approximately 300 m^3/day. Based on the hydrological assessment, it was determined that the mass flow rate of raw wastewater mixing with the water in the warm-water channel was 0.00347 kg/s, calculated using a normalized concentration of 1 kg/m^3. Based on the calculations, it has thus become clear that, due to mixing, the chemical components of the 3.5 l/s wastewater discharged into the warm-water channel with a water flow rate of 100 m^3/s reach the Danube in such low concentrations – even in their untreated state – that they are largely below the limit of detection, and represents a negligible load from the perspective of the receptor components of the biosphere.

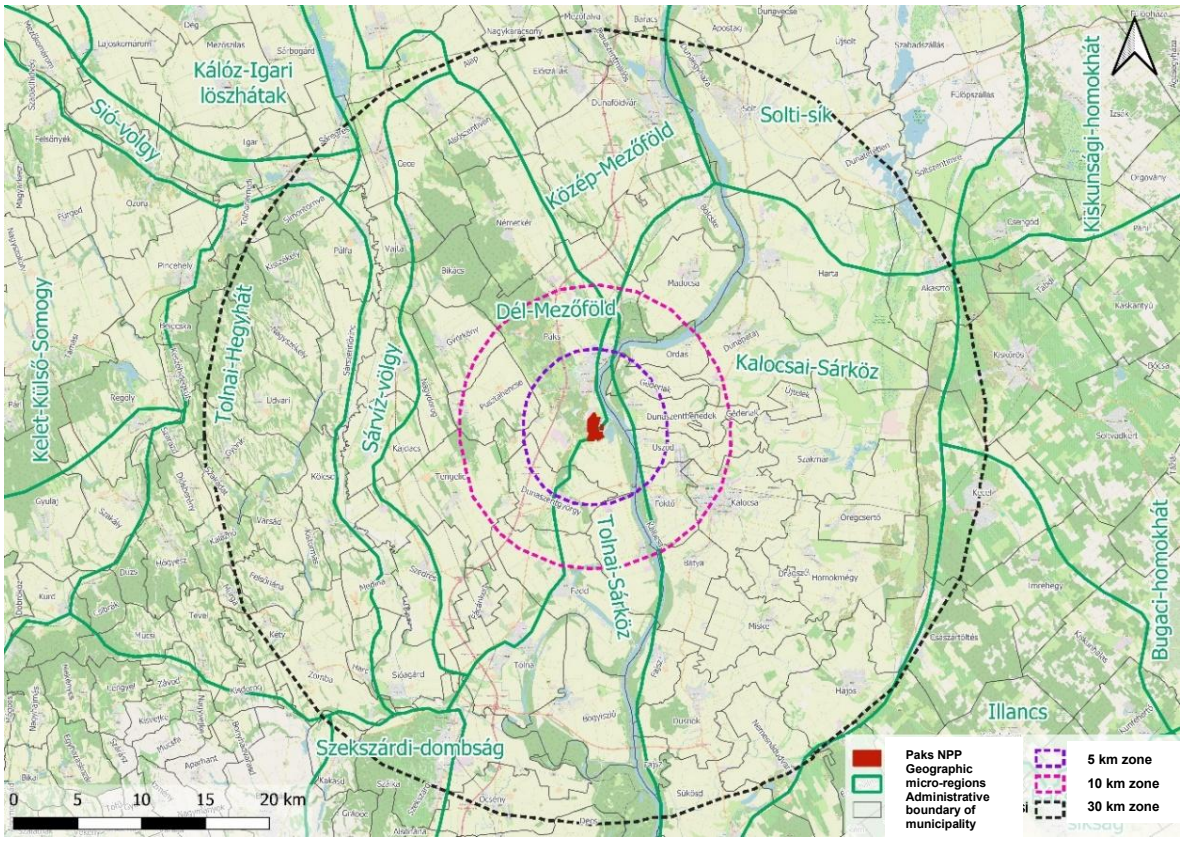
4.5.3.8. Potential transboundary environmental impacts

Provided that all applicable laws, environmental regulations, and obligations regarding the independent operation of the Paks NPP and its joint operation with Paks II NPP are complied with, no transboundary environmental impacts are expected to occur with respect to the investigated groups of organisms. This is supported by the fact that neither the direct and indirect construction-related biosphere protection impact areas identified in connection with the preparation of the SSLE, nor the operational biosphere protection impact areas identified for the SSLE period in connection with the operation of the NPP, come close to the national border.

4.6. Impacts on the landscape and land use

Landscape-scale assessments generally consider a more extensive area than those conducted for the impacts of the planned activity on other environmental medium and systems within the environmental impact assessment. During the previous environmental impact investigation also regarding the Paks NPP and its first service life extension, investigations at the landscape scale were conducted within a 30 km radius around the facility, fundamentally concerning the spatial structure and land use. Therefore, to assess the impacts of the SSLE, a 30 km assessment area was designated in this case as well for the SSLE, which also provided an opportunity for comparison with previous states.

The investigation of landscape characteristics was conducted with increasing detail when approaching the facility. A closer, approx. 10 km radius, as well as an immediate vicinity (3-5 km) were also designated. The physical geographical and landscape features were analysed in the broader environment, primarily the visual landscape characteristics in the closer environment, and the landscape structure and land uses in the immediate vicinity. The spatial layout of this threefold division; i.e., the assessment area, is presented in *Figure 4.6-1*.



Source: Own editing based on the Geographic Micro-regions of Hungary (MTA FKI) – GIS (novenyzetiterkep.hu/node/407)

Figure 4.6-1. The NPP and its vicinity within 30, 10, and 5 km, and the geographical micro-regions located there

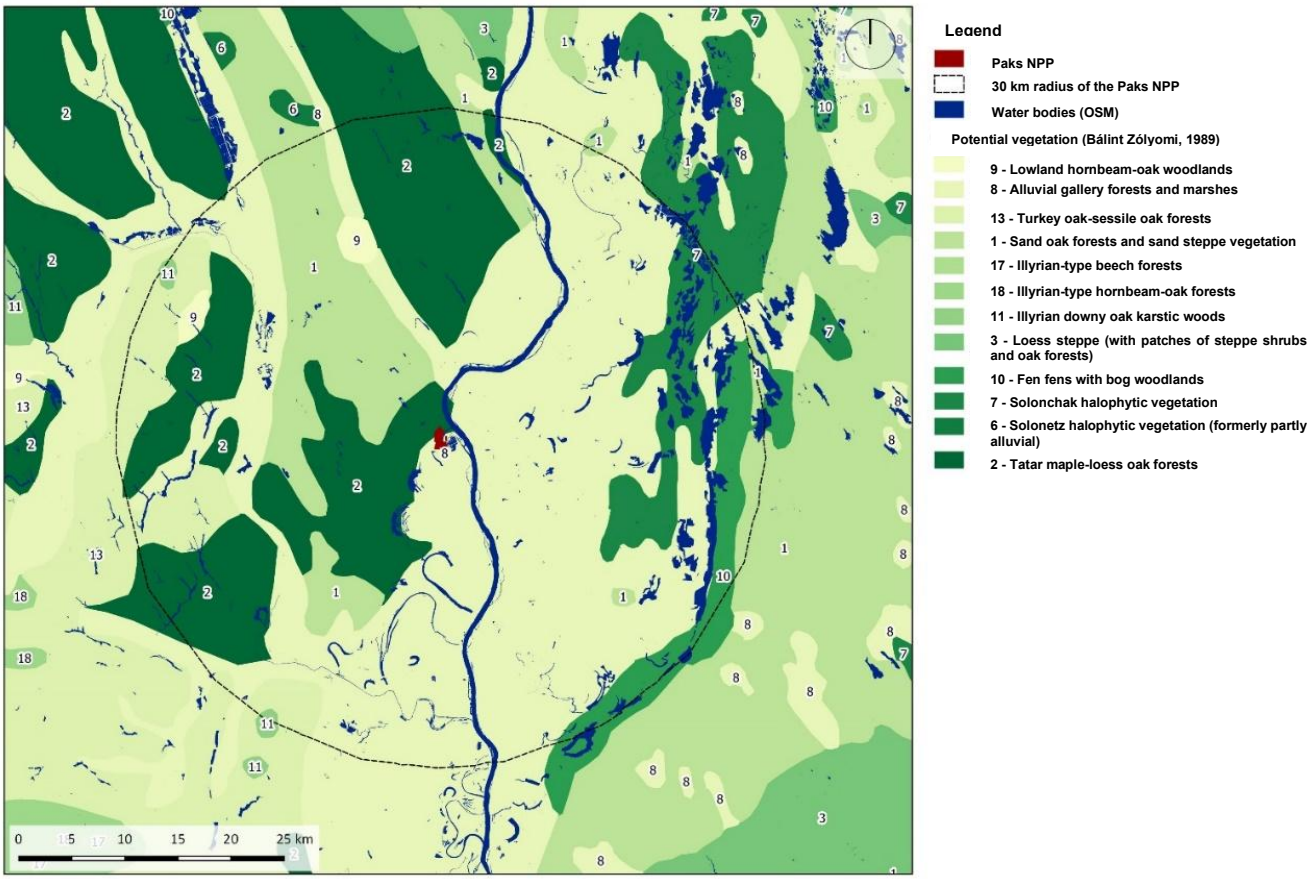
4.6.1. Landscape characteristics of the current state

4.6.1.1. Physical and landscape geographical position, and landscape history of the region

The region falling within the 30 km radius of the Paks NPP is situated in the Danube-Tisza Basin macro-region, within the Great Hungarian Plain and the Transdanubian Hills macro-region sections; within these, it forms part of the Mezőföld, the Danube Valley Plains, and the Tolna Hills meso-regions. The location of the micro-regions affecting the assessment area is presented in *Figure 4.6-1.* of *Chapter 4.6*. The town of Paks and the NPP site itself are located in the South Mezőföld micro-region. The assessment area is largely flat, significantly influenced by human interventions, meaning that near-natural vegetation has been preserved only in fragments.

The first investigation point in landscape history is the presentation of the natural characteristics that developed over the longer term prior to, or in the absence of, human landscape-shaping activities. Based on the Bálint Zólyomi vegetation map (1989), the assessment area was primarily occupied by Tatar maple-loess oak woods, loess steppes, alluvial gallery forests, and marshes (*Figure 4.6.1.1-1.*).

The landscape history of the NPP and its vicinity is inseparable from the history of the town of Paks. *'Thanks to its favourable geographical conditions – a location along the Danube on a low valley plain, bordered by a loess plateau – Paks has been an inhabited area since prehistoric times. Land use has been determined by landscape features since historical times, meaning that fishing, forestry, vineyards, and agricultural land use coexisted characteristically for centuries*.' The earliest archaeological finds, consisting of polished Stone Age tools, were discovered on Sánchegy. In the 1st century AD, Paks was part of the Pannonia province of the Roman Empire, whose border, and later defensive line, was formed by the castrum of Lussonium, constructed on Sánchegy in the 4th century AD.



Source: Own editing based on the Geographic Micro-regions of Hungary (MTA FKI) – GIS (novenyzetiterkep.hu/node/407)

Figure 4.6.1.1-1. Potential vegetation types within a 30-km radius of the power plant

From 1730 onwards, alongside the primacy of agriculture, guild-based industry also gained ground in the settlement, which held market town status. This expansion was accompanied by the growth of the settlement itself, meaning an increase in built-up areas (areas exempt from cultivation). Viticulture and wine production in the region were outstanding during this period. The map of the first military survey from the 18th century reveals extensive arable lands and vineyards, as well as wetlands, marshes, and fens south of the town. On the second military survey, the expansion of the town is noticeable; along the road following the route of the current Main Road No. 6, a new district named “Új-város” was established by draining the former marshland. Water management also extended to the regulation of the Danube; in 1841, based on the plans of József Beszédes, the Imsós and Várszeg bends were cut through between Paks and Ordas.

The cut-off of the Danube bend brought a boom in trade, as the main current of the Danube moved into the immediate vicinity of the town. Consequently, due to the change in the direction of the water current, the construction of groyne structures became necessary, which enabled the operation of a whole series of ship mills. The operation of the ship mill fleet and the millers' guild played a decisive role in the commercial development of the town during this period.

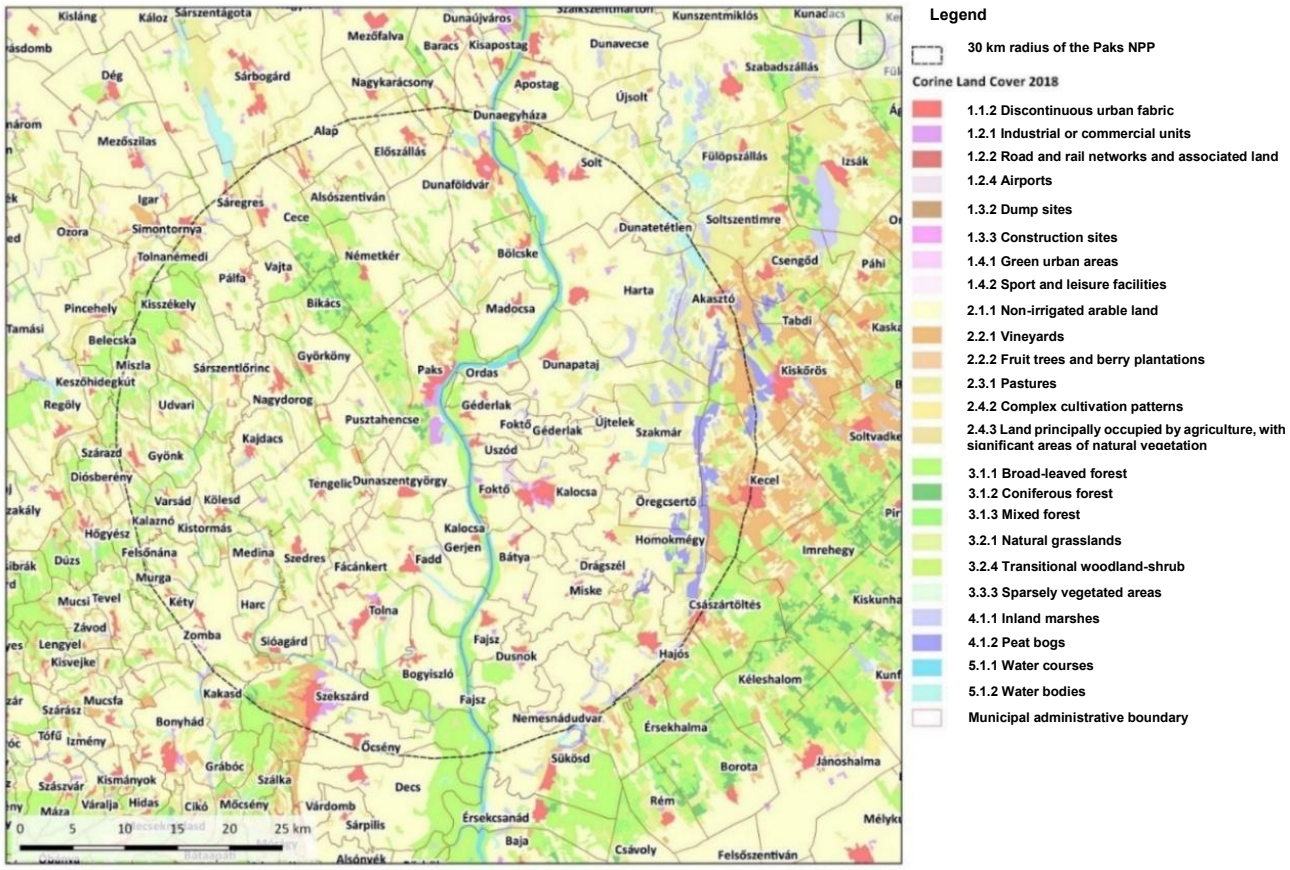
The early 19th century was characterized by slow bourgeois development, and then, despite the Great Depression, industrialization commenced during the interwar period (when the predecessor of the later cannery began its operations), culminating after World War II. In the first half of the 20th century, economic growth was significantly limited by the fact that the Danube bridge was constructed in Dunaföldvár rather than here, which also led to the cancellation of the development of the Paks-Tolna-Mözs-Szekszárd railway line. Concurrently, ship mills on the Danube were gradually replaced by steam mills.

Following this, a period of slow decline began in the life of the settlement, which was reversed by the construction and commissioning of the Paks NPP's four reactor units between 1973 and 1987, giving a new impetus to the town's economic and social development that persists to this day. The construction of the power plant transformed Paks into one of the most dynamically developing settlements in the country.

4.6.1.2. Land cover, land use, and landscape structure

Mapping of land cover and land use, as well as the characterization of the land structure, were conducted at three scales, similar to the EIA carried out for the first service life extension of the Paks NPP. Based on the available 1990 and 2018 Corine Land Cover (CLC) databases, it can be concluded that land use in the broader region did not change significantly between the two time points; the changes can be summarized as follows (land use in 2018 is shown in *Figure 4.6.1.2-1.*):

- the proportion of built-up areas has increased slightly, but despite this increase, it still lags behind the national average (approx. 4.8%),
- the proportion of transportation areas and disturbed surfaces also increased slightly, but their total area accounted for only 0.4% of the investigated area,
- The area of arable land decreased by nearly 1%, mainly due to urban development, infrastructure projects, and an increase in forested areas. However, arable land still accounts for the majority of land use in the region (nearly 63%),
- the area of vineyards and orchards also decreased by approximately 1.1%,
- the area of grasslands increased slightly (by approximately 0.3%), while the area of mosaic agricultural areas decreased slightly (by approximately 0.1%),
- the proportion of forest areas and transitional woodland-shrub areas, which represent the second most characteristic land use in the region (nearly 14%), increased by 1.3% during the examined period,
- there has been a decrease of nearly 1,000 hectares in the area of marshes and swamps, which indicates the aridification of the region,
- however, the extent of water bodies increased by more than 500 ha (this was primarily due to the actual water surfaces of certain salt lakes).



Source: Own editing based on Corine Land Cover 2018 (Copernicus Land Monitoring Service)

Figure 4.6.1.2-1. Land cover within 30-kilometre radius of the Paks NPP, 2018 (based on CORINE Land Cover 2018)

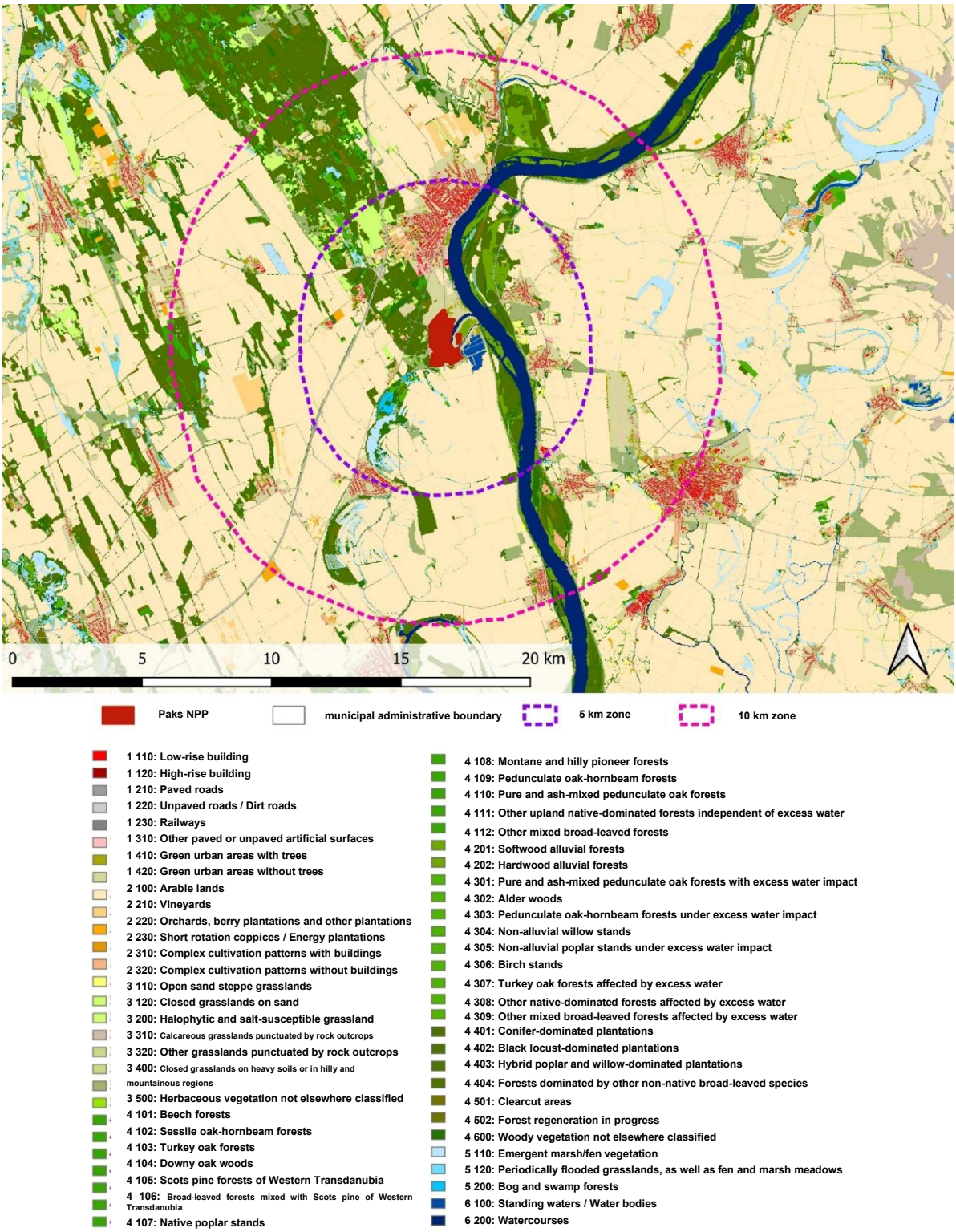
The situation is similar in the immediate vicinity of the site. Here, changes between 1977 and 2018 can be assessed as follows:

- the expansion of the road and rail networks was also reflected in land-use ratios (their share increased from 0.2% to 0.54%),
- the area under vineyards has decreased (from nearly 2% to 0.7%),
- the share of land covered by significant natural vegetation in primarily agricultural areas increased by nearly 2%,
- the spatial decrease of natural grasslands was more than 2% (more than 700 ha of natural grassland disappeared),
- at the same time, forest areas increased by nearly 2% (part of which may be a consequence of the spontaneous afforestation of grasslands)
- the spatial extent of water courses and canals also decreased by nearly 1%.

The National Ecosystem Base Map (NÖSZTÉP) provides a more detailed picture compared to the Corine database, as it works with a 20x20 m raster grid instead of 500x500 m basic units. The land uses within a 10 km radius of the power plant are shown in *Figure 4.6.1.2-2*. Based on the figure, the defining elements of the landscape structure – alongside arable lands, forests, and to a lesser extent, grasslands, vineyards, orchards, and built-up areas – are linear technical infrastructure elements.

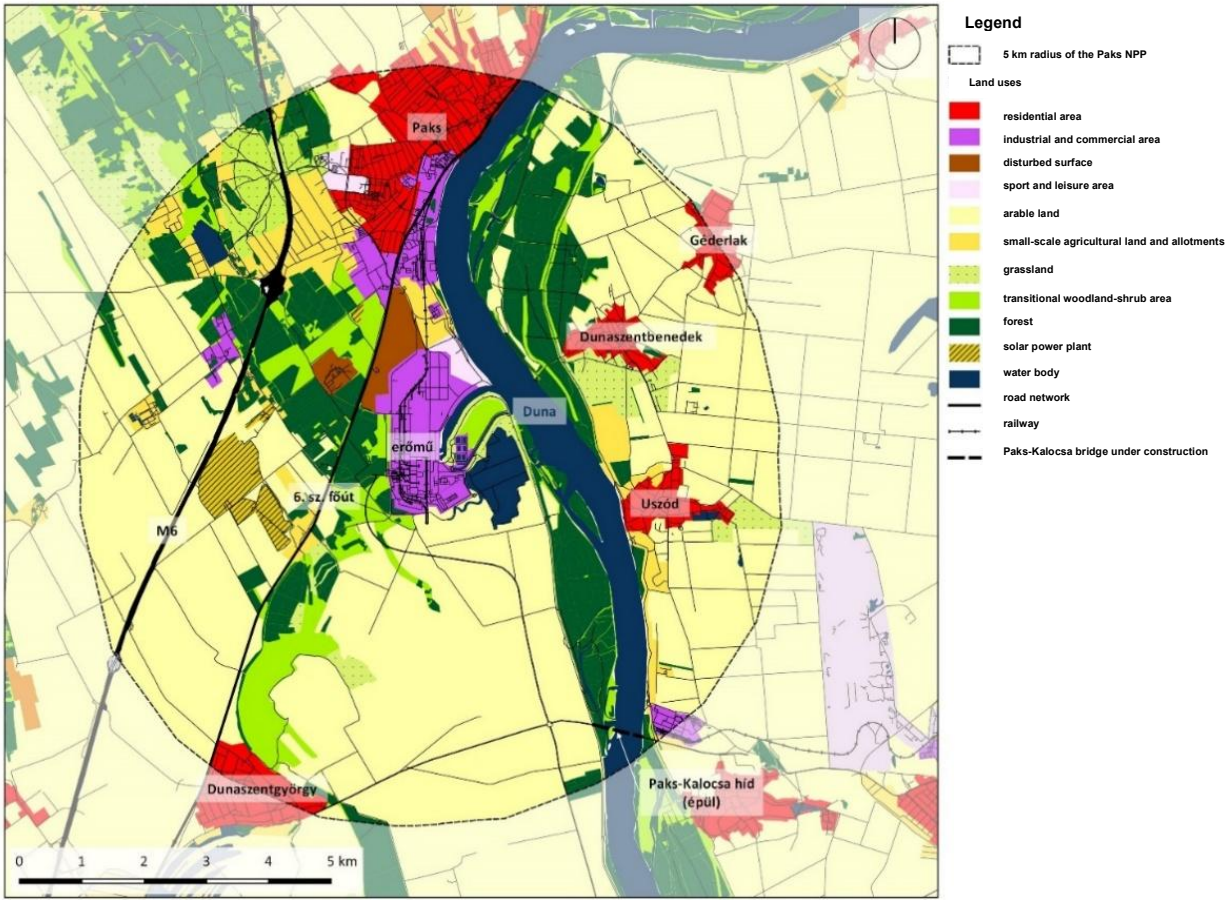
Based on Open Street Map, Corine Land Cover 2018, 2023 Google Earth aerial photographs, and a 2024 field survey, an updated land use map within a 5 km radius of the power plant was prepared, which is shown in *Figure 4.6.1.2-3.* The map reveals that the recent construction of solar power plants has also significantly affected the Paks region. Due to their extent, the solar power plants located in the vicinity of the power plant have become defining elements of the landscape structure (approx. 140 ha within the 5 km radius of the power plant). Furthermore, due

to the construction of Paks II NPP, the proportion of disturbed surfaces in the vicinity of the power plant is also significant (approx. 80 ha adjacent to the power plant site designated as an industrial area).



Source: Own editing based on http://alapterkep.termeszetem.hu/

Figure 4.6.1.2-2. Ecosystem types within 10-kilometre radius of the Paks NPP



Source: Own update based on Open Street Map (25.03.2024), Corine Land Cover 2018, 2023 Google Earth aerial photographs, and a 2024 field survey

Figure 4.6.1.2-3. Land use within 5 km radius of the Paks NPP

Landscape potential refers to the “capacity of the landscape”, meaning its suitability for specific uses. Through its current land use and natural attributes, the examined landscape section possesses high ecological potential as well as – due to its land uses – high agricultural and forestry potential. Thanks to the Paks NPP and the Paks Industrial Park, the industrial potential of the region is also high, which is expected to strengthen further, partly due to the construction of Paks II NPP and partly through improved road accessibility provided by the new Danube bridge (Tomori Pál Bridge).

4.6.1.3. Landscape values

Landscape values include valuable natural landscape elements, protected natural areas, traditional land uses, as well as the values of the built heritage. Landscape values were examined within the landscape and settlement environment across three landscape scales (0-5, 5-10, and 10-30 km radius). The landscape values of the immediate vicinity are as follows:

- Landscape values listed in the County Repository of Values: Paks: churches and chapels, statues, residential houses, mansions, cellar village, thermal bath, Danube bank; Uszód: Péter Benedek Memorial House.
- Protected natural areas and assets of national importance: Dél-Mezőföld Landscape Protection Area, Dunaszentgyörgy Marsh Forest Nature Reserve, 'ex lege' protected marsh in the northern part of the Dunaszentgyörgy Nature Reserve.
- Nature reserves of local importance: Paks: Front Garden of the Ferenc Deák Street Primary School Nature Reserve, Garden of the City Museum Nature Reserve, Garden of the Paks Roman Catholic Church and the Church Square Nature Reserve.

- Natura 2000 sites (with identification codes): Tolnai Duna (HUDD20023), Paksi Ürgemező (HUDD20069), and Dunaszentgyörgyi-láperdő (HUDD20072) Special Areas of Conservation.
- Elements of the National Ecological Network: core area, ecological corridor.
- Areas of the Landscape Protection Zone: overlapping with protected natural areas of national importance, Natura 2000 sites, forest areas, and water bodies.
- Managed forest areas: approx. 1,570 ha.
- Arable lands with excellent and good site conditions: both excellent and good arable land are present in smaller proportions, covering an extent of approx. 580 ha southwest of the power plant.
- Vineyard areas within wine regions, vineyard areas under protected designation of origin: Tolna wine region: areas south of Paks (allotment and small-scale garden areas) classified as Class I and Class II areas in the official vineyard site register.
- Unique landscape values: crucifixes, residential houses, draw wells, a local heritage house, wetlands, monuments, and public statues in the settlements of Uszód, Dunaszentbenedek, and Géderlak (according to the database of the Nature Conservation Information System[8]).

4.6.1.4. Major land-use conflicts and land-use values associated with the NPP

A land-use conflict arises when two land-use activities interfere with one another in some way. In the vicinity of a power plant, the most notable conflicts involve linear infrastructure elements related to the operation of the NPP. Among these, the presence of transmission lines (electricity and district heating lines) is of regional significance. In principle, the Kalocsa airport could also be one, which, however, currently serves civil (recreational sports) purposes, and the airspace of the NPP remains a prohibited area for civil aviation, thus no conflict exists.

A land use value associated with the power plant can be identified as the water transfer to the Fadd Danube Oxbow Lake through the Paks-Fadd channel – utilizing the condensate water from the NPP's high-capacity office air conditioning systems – to ensure good water quality and adequate water levels in the oxbow lake, the supply of fresh water to the fishponds, as well as the district heating supply of the Kishegy residential area utilizing the waste heat of the power plant.

4.6.1.5. Landscape, landscape character

The landscape is primarily defined by topography, vegetation cover, and land use. Water bodies (primarily the Danube), the vegetation lining the watercourses, and the extensive grasslands are of outstanding scenic value in the region. These generally also enjoy nature conservation protection and, at the same time, fall within the landscape protection area zone designated in the National Spatial Plan (OTrT). Landscape scars occur within the examined landscape section (e.g., open surfaces remaining from the construction of the Paks II NPP and the Tomori Pál Bridge, with landscape rehabilitation currently in progress for the latter). However, these represent temporary conditions. Distinct, adverse landscape elements include the existing overhead power lines, mobile phone masts, and radio towers.

According to the mapping of National Landscape Character Areas, the examined landscape section lies at the meeting point of the Middle and Lower Danube Valley and the Mezőföld landscape character areas. Here, the national landscape character types of 'arable-dominant homogeneous plains landscape', 'forest-water-dominant river landscape', 'forest-dominant mosaic plains landscape', and 'arable-dominant, mosaic, undulating plains and hills landscape

[8] In the case of Paks, neither the Local Spatial Development Plan nor the Municipal Townscape Decree mentions any unique landscape values, and the Nature Conservation Information System contains no relevant data. Based on the site visit, the memorial site of the 1887 ferry disaster, located in the immediate vicinity of the power plant, can be identified as a unique landscape value

with watercourses and forest patches' are characteristic. The power plant itself – together with the town of Paks – belongs to the 'urban landscape on waterfront' landscape character area.

The reactor buildings of the Paks NPP – with associated chimneys reaching a height of 100 m – can be seen from a distance of up to 5-10 km under good visibility conditions, given that the power plant was built on a nearly flat area with a low elevation above sea level. From a distance of 10 km, however, the outlines of individual buildings are barely distinguishable, and the tops of the reactor buildings are perceived merely as point elements. Within the examined area, the specific viewpoints from which the landscape unfolds are of key importance. The expected changes in the landscape were the subject of investigation from 19 frequented viewpoints. Based on these, it can be established that according to the location of the frequented viewpoints and the view-obstructing elements, the actual visibility is around approximately 8 km with the naked eye under clear weather conditions. From the residential area closest to the power plant – the inner area of Uszód – the buildings of the power plant are not visible due to the flood protection dike and the extensive forest areas.

The power plant appears prominently primarily from the road network in its vicinity (northern and southern access roads), certain sections of Main Road No. 6, the inner area of Paks (especially from local viewpoints, such as the Gárdonyi Lookout Tower and the elevated points of the residential estates), and the road network connected to the Tomori Pál Bridge.

4.6.2. Impacts on the landscape

4.6.2.1. Current operations

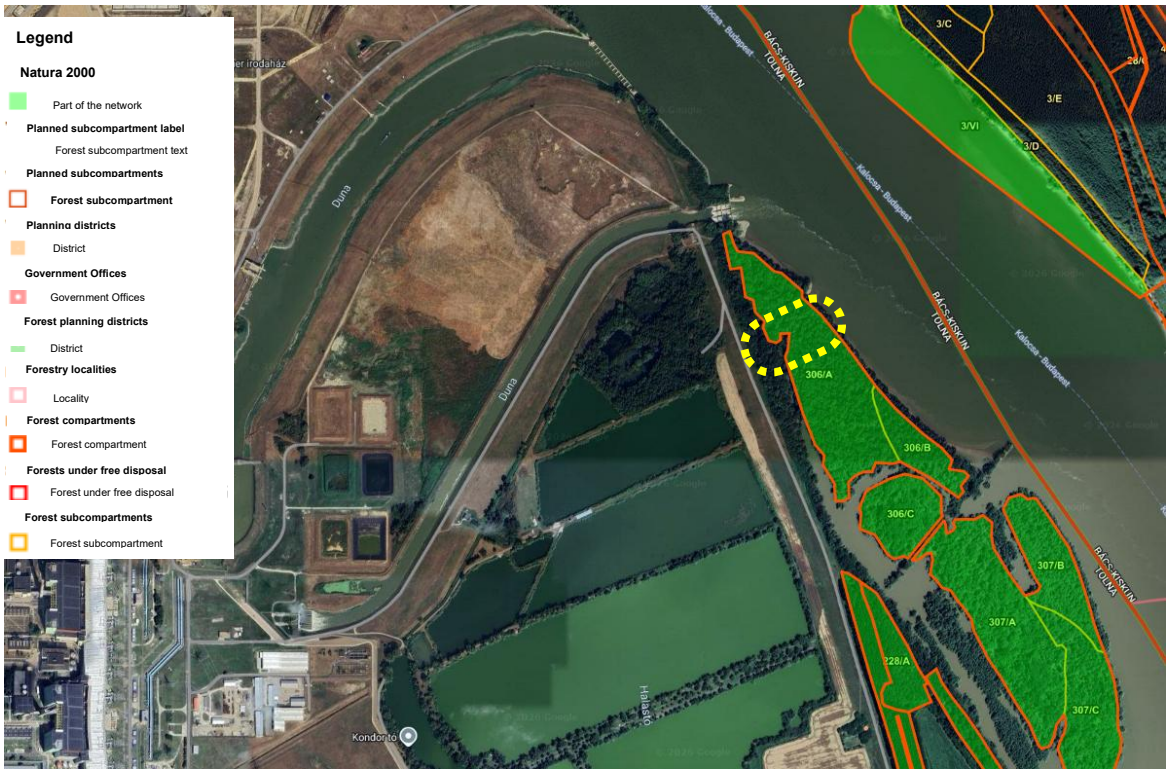
From a landscape perspective, the effects of the NPP's operation are consistent with the characteristics of the baseline condition, as the plant's existence and operation have shaped the current landscape and land-use structure, the landscape character (land use, associated elements such as the power transmission line network, housing estates, utilities, and public institutions), and have influenced the landscape's potential (e.g., the emergence of industrial potential) and the landscape's appearance.

4.6.2.2. Impacts of preparations for the SSLE

From a landscape perspective, land use is generally the most significant impact during the preparatory phase. In this case, however, it will result in only minimal changes, as an existing facility generally does not require the use of additional land. The reconstruction and renovation work required as part of the preparation for the Paks NPP's SSLE will be carried out within the site. An exception to this is the land required for the alternative warm-water channel section and the connected peak cooling system (*Chapter 2.2.2.1.*), which are planned to be implemented during the preparation phase and will be necessary in the event of the joint operation of the two NPPs. Its location was designated south of the current warm-water channel, partly within the industrial area and partly occupying alluvial areas and parts of the fishponds, largely remaining within the site of the Paks NPP. More than half of the required land acquisition is already part of the site and is classified as an industrial area. (The Paks NPP site covers approximately 560 hectares; the area to be used outside the site constitutes a fraction of this, approx. 1.8%.)

Out of the total occupied area of 21.25 ha, according to current land use, 0.65 ha is managed forest (outside the industrial area) and 3.47 ha is fishponds. Nearly 1.9 ha is part of a Natura 2000 site. Given that the accessibility of the warm-water channel section located in the floodplain must be ensured in the long term, during the operation period, the acquisition of 0.78 ha of managed forest and 2.1 ha of Natura 2000 site must be anticipated compared to the current state.

Based on the forest map published by the Forestry Directorate of the National Food Chain Safety Office (NÉBIH), the planned alternative warm-water channel section affects forest sub compartment No. 306/A, located south of the existing warm-water channel in the area between the flood protection dike and the Danube (*Figure 4.6.2.2-1.*). This area is formally registered under the 306/A designation, indicating a specific forest sub compartment subject to regulatory oversight.



Source: Forest map available on the website of the Forestry Directorate of the National Food Chain Safety Office (NÉBIH) (erdoterkep.nebih.gov.hu)

Figure 4.6.2.2-1. The managed forest area affected by the planned alignment of the alternative warm-water channel section

The area planned for acquisition, displaying the affected forest sub compartment No. 306/A on a site plan with a scale of 1:10,000, is shown in *Figure 4.6.2.2-2.* The data of the forest sub compartment are presented in *Table 4.6.2.2-1*. Based on the table data, the affected forest sub compartment consists of a willow stand, holds a water protection designation, is a non-protected derivative forest, and forms part of the Natura 2000 network.

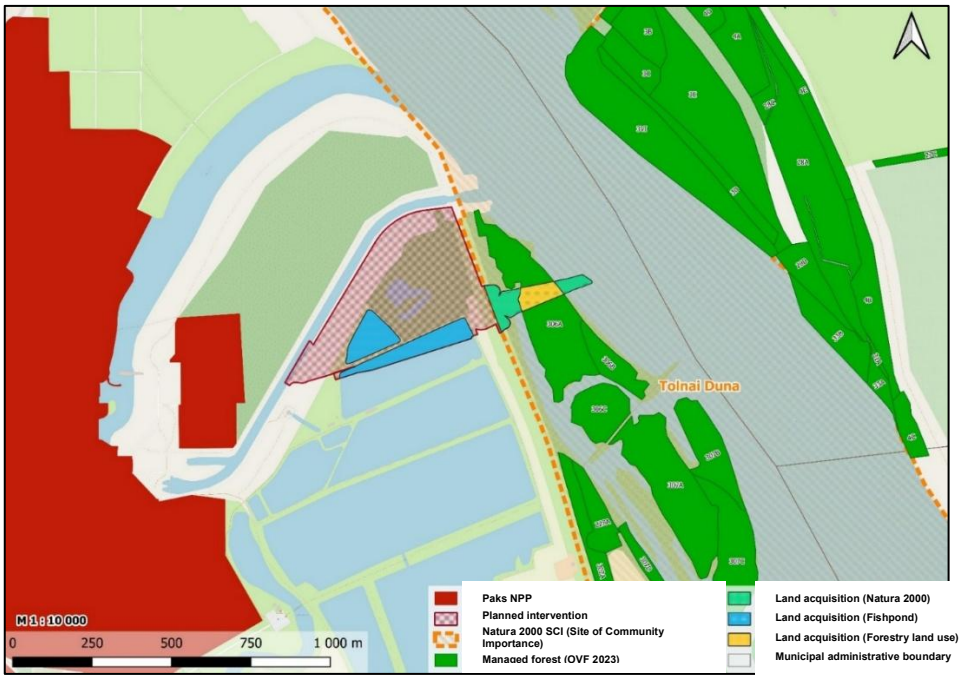


Figure 4.6.2.2-2. Areas used for the installation of the alternative warm-water channel section and the connected peak cooling system

Table 4.6.2.2-1. Data of the affected forest subcompartment No. 306/A

Competent County Government Office	BCGO
District	Nagydorog District
Locality (code)	Paks (7550)
Topographical number	Paks 0109/8
Compartment	306
Subcompartment letter (code)	A (10)
Area	7,43 ha
Forestry region	Middle and Lower Danube Floodplain
Ownership type	State-owned
Primary designation	Water protection
Additional designation	Natura 2000
Forest stand type	Willow stand
Naturalness status	Derivative forest
Baseline naturalness requirement	Derivative forest
Protection status	Non-protected area

Pursuant to Section 82 (4) of Act XXXVII of 2009 on forests, forest protection, and forest management, the forestry authority must prescribe compensatory afforestation in the case of the acquisition of managed forests of 0.5 ha or more for natural and semi-natural forests, and 1 ha or more for forests with other classifications. In the present case, the planned acquisition affects a derivative forest covering an extent of 0.78 ha. Therefore, compensatory afforestation is not mandatory, and the acquisition can be implemented through the payment of a forest preservation fee.

Regardless of this, it is recommended that instead of the acquired area, a new forest be planted as a protective woodland in the area proposed for afforestation by the National Spatial Plan (OTrT), expediently in the vicinity of the power plant.

The justification for the planned land acquisition is the construction of the peak cooling system and the alternative warm-water channel that enables the reduction of the thermal load on the Danube during critical periods, which is necessitated by the joint operation of the Paks NPP and the Paks II NPP. The implementation of the peak cooling system, along with the construction of the new warm-water channel section and the Danube intake point will ensure compliance with the prescribed temperature limits for the Danube’s water temperature even under critical weather conditions – which are expected to occur more frequently in the future due to changing climate conditions – without the need for operational interventions. The planned intervention is therefore in the public interest.

The required additional land acquisition modifies land use to the extent that in the affected areas, the previous, mainly forestry land use will be replaced by industrial land use; the natural and semi-natural area will fall under anthropogenic influence and take on an artificial appearance. This relatively low-volume change will not have a significant impact on the landscape structure or the landscape character. Therefore, the consequence of the land use change is rated as acceptable. (Its necessity is justified by the mitigation of conflicts regarding other land uses, such as the water quality and biosphere of the Danube.)

The acquisition of the alluvial forest along the Danube can be designated as a change in landscape value due to the co-location of the alternative warm-water channel section and the peak cooling system elements necessitated by the joint operation of the two NPPs. The construction will also cause a visual change in the landscape, as the 'absence of the forest' will be more characteristic in the view than the sight of the new channel or the cooling cells, which will be partly screened by the dike. No significant visual change is to be anticipated even due to the clearing of the forest patch, given that similar forest patches are located in the background, on the islands, and on the opposite side of the Danube. The impact is tolerable.

Among the surrounding land uses, the installation and construction of the planned new elements will at most affect the recreational use of the fishponds located to the south and southwest. However, this will only last for the relatively short duration of the canal construction and equipment installation, in an acceptable manner.

4.6.2.3. Impacts of the independent operation of the Paks NPP

When assessing the independent operation of the Paks NPP, the baseline scenario is the termination of extended operation and the cessation of electricity generation. No increase in land use is expected during the period of continued operation. Land use and land structure will not change due to the cessation of operations either, as the site is expected to remain an industrial area for a long time even after the cessation of energy production. From this perspective, the impact is neutral.

Since this is an existing, operational power plant, the landscape structure is not expected to change during continued operation; the current landscape structure was established during the construction and/or operation of the NPP and its associated facilities, meaning that the impact on the use of the surrounding areas has already occurred.

No new types of land use conflicts, or conflicts on a different scale than those seen so far, are expected to arise during continued operation. 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-flow water discharges decrease or the water temperature increase to such an extent that it may become necessary to restrict the operation of the NPP. However, this is expected to occur only for short periods in the future, 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 expected to be neutral.

It can be considered an improving effect that the beneficial impacts exerted on the surrounding land uses (the operation of the fishpond system, the improvement of the water quality and quantity of the Fadd Danube Oxbow Lake, and the district heating supply of the residential area) can be sustained over the longer term through the service life extension.

The planned service life extension is expected to have no influence on the preservation of protected assets. An exception to this is the forestry land use affecting the Danube floodplain due to the construction of the alternative warm-water channel section and the new Danube discharge point. However, this will be implemented only within a very small area of the Danube floodplain. Furthermore, similar alluvial forests will remain adjacent to the acquired areas, meaning that the loss of value is negligible from a landscape protection perspective. The impact exerted on landscape values is rated as neutral.

Changes in landscape and landscape character are generally linked to the construction of a facility. In the case of an operating plant, visual changes in the landscape no longer need to be anticipated. The landscape character represented by the facility during the service life extension 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. From this perspective as well, the impact can be judged as neutral.

From a landscape use perspective, the narrower, 3 km area around the NPP can be designated as an impact area. The visibility of the power plant, both currently and during the service life extension period, extends to sub-areas within an approx. 8 km radius of the power plant that are not affected by screening (fundamentally the screening by forests and settlement structures). From a landscape perspective, this can be considered the impact area (*Figure 4.6.2.3-1.*).

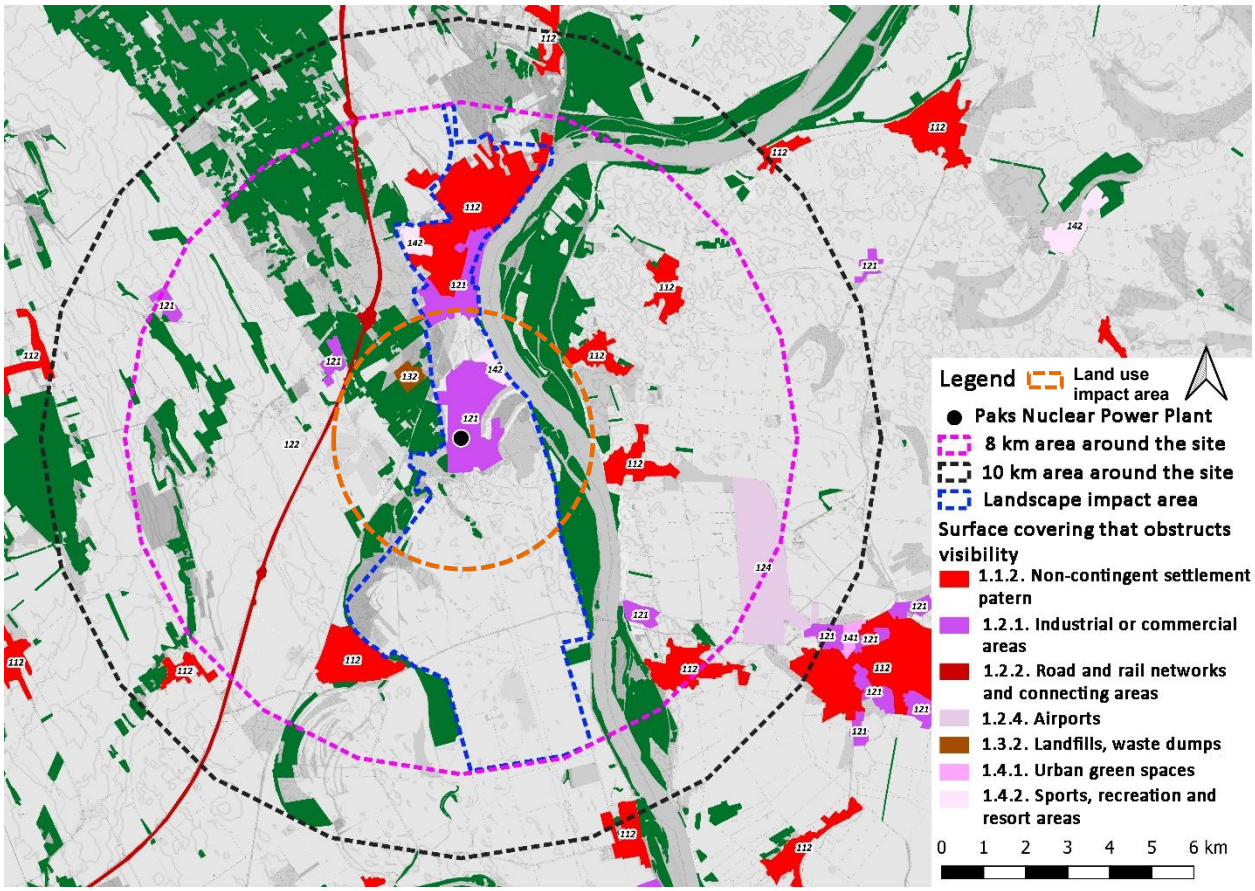


Figure 4.6.2.3-1 Landscape and land use impact area

4.6.2.4. Combined impacts of nuclear facilities currently operating and planned at the site

The impacts of the joint operation of the Paks NPP and the Paks II NPP were already examined during the environmental licensing process for Paks II NPP, but only a relatively short period of joint operation was taken into account. The SSLE extends this period by 20 years, meaning that any potential impacts will thus last for a much longer period. From this perspective, however, a new element emerges: to ensure that the combined thermal load of the two NPPs on the Danube remains within safe regulatory limits, the Paks NPP – as mentioned in the preparatory phase – also plans to implement an alternative warm-water channel section and a peak cooling system.

Land use and landscape use will remain unchanged, as the Paks II NPP site was previously designated as an industrial area reserved for the expansion 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, the functionality of which will change substantially with the addition of electricity generation activities. The construction and operation of facilities and infrastructure directly and indirectly related to the operation of the Paks II NPP (e.g., transportation links, power lines connected to the electricity grid) will entail changes).

Taking into account the joint operation of the two NPPs, temporary storage must also be provided during the SSLE period for spent fuel assemblies generated at the Paks NPP and those generated during the operation of the Paks II NPP. Providing interim storage is the responsibility of PURAM, which ensures the interim storage of the spent fuel assemblies generated at the Paks NPP in a Modular Vault Dry Storage (MVDS) facility at a site adjacent to the Paks NPP. To date, 28 storage vaults of the modular storage facility, which was commissioned in 1997 and has been continuously expanded, have been completed. The interim storage of the entire volume of spent fuel assemblies generated during the current service life extension will be manageable within the licensed storage facility, which will have a total of 33 vaults. PURAM plans to implement the interim storage of spent fuel assemblies generated during the SSLE period and at the Paks II NPP

using a commercially available, reference-based new technology that does not require the expansion of the area designated for interim storage related to the Paks NPP. A description of the technology is provided in *Chapter 2.2.2.4*. Expanding the capacity of the interim spent fuel storage facility (SFISF) will therefore only involve the development of vacant areas within the facility's existing site. Since, in this case, both the additional land acquisition and the modification of land use are taking place in an industrial environment, the combined impact of the facility's appearance and operation can be considered tolerable.

An intensification of land use conflicts in the immediate vicinity is not anticipated. The operation of the alternative warm-water channel section and the peak cooling system may potentially exert an adverse impact on the recreational activities of the adjacent fishponds due to its noise impact. However, the operation of the cooling system will only be required periodically, during critical coincidences of high Danube water temperatures and high air temperatures; meaning that the equipment is expected to operate only for short periods. The majority of the fishpond users are interested in the operation of the power plant, so they are expected to accept this short-term adverse impact due to the beneficial impacts of the service life extension. Therefore, the impact can be assessed as acceptable.

An exception to this, meaning an intensification of conflicts from a land use perspective, may arise in connection with water use and the discharge of cooling water warmed by the technology into the Danube, due to the joint operation of the two NPPs. The decrease in discharge rates, combined with the increase in water and air temperatures during the hottest summer periods, necessitated further measures to ensure compliance with the thermal load limits applicable to the Danube. The technological modification currently included in the plans (cooling equipment), as well as the discharge of the warmed cooling water further south than at present, and the operational solutions (maintenance scheduling, load reduction) can mitigate the emergence of this conflict, the resulting situation, and its environmental consequences. The conflict can therefore be considered manageable, and its impact tolerable. This applies not only to potential conflicts between the two NPPs but also to potential conflicts with other water users.

No detectable change is anticipated in landscape values even in the case of the joint operation of the two NPPs. During the construction works related to the implementation of Paks II NPP, the extent of the Tolnai Duna Special Area of Conservation Natura 2000 site (code: HUDD20023) decreased to a minimal extent, and it will further decrease minimally with the construction of the new alternative warm-water channel section. However, this loss of value is minimal, as established in the associated Natura 2000 impact assessment. The same applies to the acquisition of alluvial forests, given that similar forests will remain adjacent to the acquired area. The impact exerted on landscape values can thus be rated as tolerable.

In the industrial environment, the operation of Paks II NPP will not cause a significant change in the landscape character, as the height and massing of the planned two new units are similar to the operating Paks NPP. The joint appearance of the two NPPs is expected to be tolerable in the landscape view, as shown in *Figure 4.6.2.4-1*.

The alternative warm-water channel section and the cooling cells of the peak cooling system will be located virtually entirely within the site; they will not significantly affect the industrial character of the area. Furthermore, the forest and the new embankment will partially screen the new facility and equipment. Its visibility is therefore limited. From this perspective as well, the impact can be classified as tolerable.

Conventional emergency events are not expected to have any detectable impacts on the landscape. From a landscape perspective – taking into account the distance from the national border and the estimated extent of the impact area – no transboundary impacts are anticipated.



Source: The website of Paks II. Atomerőmű Zrt. (www.paks2.hu)

Figure 4.6.2.4-1. Visual plan of the Paks II NPP displaying the buildings of the Paks NPP

4.7. Impacts on the settlement environment

The spatial structure and settlement environment investigations covered a 30 km radius around the Paks NPP, consistent with methods from previous service life extension impact assessments. This broader analysis supported the inclusion of the area in regional development and spatial planning documents while defining the facility's role in the county's structure. The 5-10 km radius must be taken into account when presenting the town of Paks, as well as when examining the relationship between the town and the NPP and during value assessment. The facility fundamentally influences the life of the settlements in the closer vicinity as a base that provides employment opportunities. With the commissioning of the Tomori Pál Bridge, which provides a road connection between Kalocsa and Paks, this opportunity has also become more easily accessible for the residents of the settlements on the left bank of the Danube.

Apart from Paks, the settlements located within the 10 km radius and therefore requiring special attention from a settlement environment perspective are the following:

- in Tolna County Dunaszentgyörgy, Fadd, Gerjen, Györköny, Madocsa, Pusztahencse and Tengelic,
- in Bács-Kiskun County Dunapataj, Dunaszentbenedek, Foktő, Géderlak, Kalocsa, Ordas and Uszód.

4.7.1. Spatial structure and settlement environment characteristics of the current state

4.7.1.1. The town and its region in national and county spatial development and spatial planning documents

Alignment with the objective system of regional development documents

Both the National Development and Spatial Development Concept and the Spatial Development Concept and Program of Tolna County regard the existing and newly establishing NPP units at

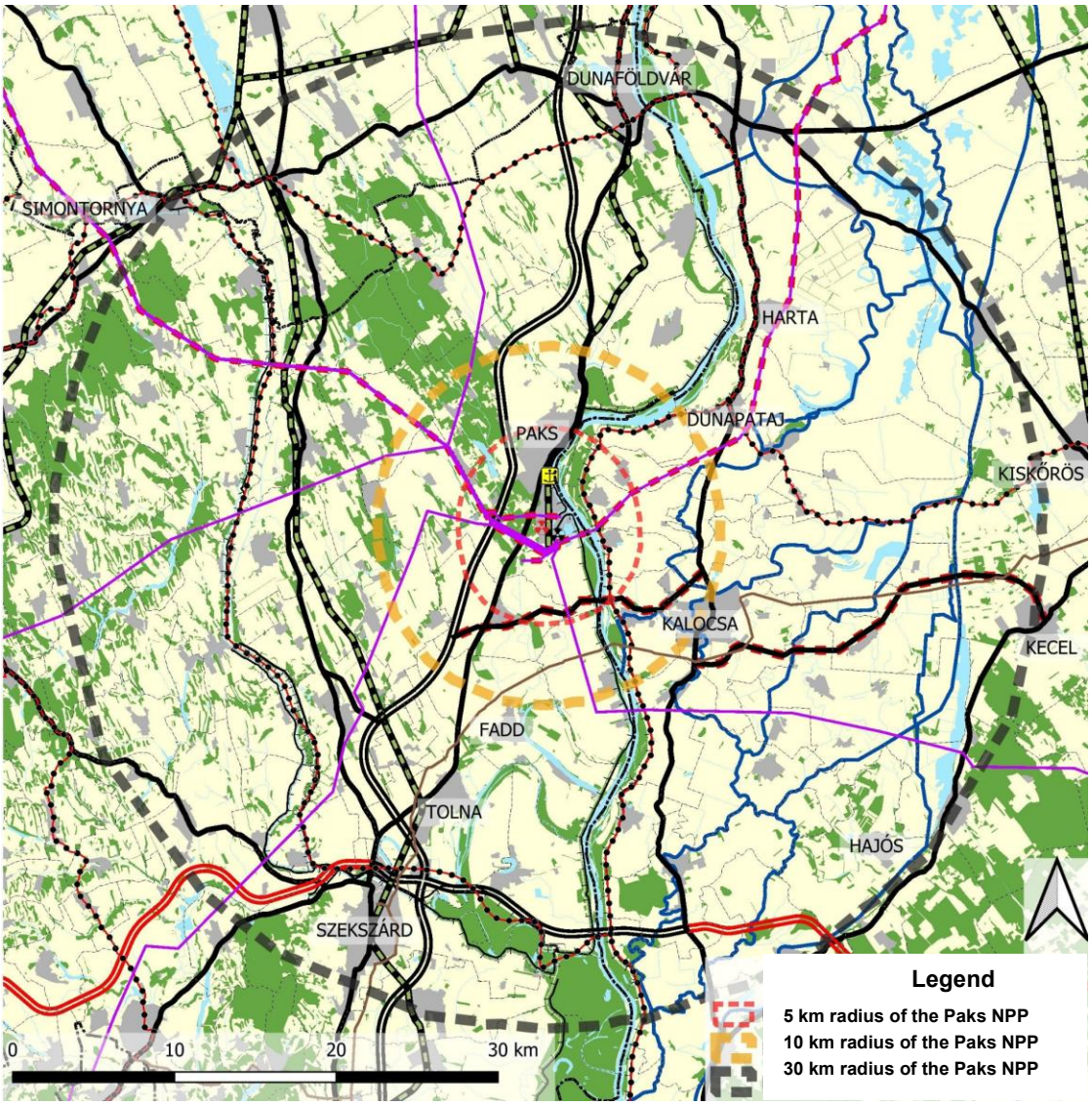
the Paks site as a spatial development asset. In this connection, they highlight the boom in the construction industry, as well as the prominent role in vocational and higher education, innovation, and research, which could become even more significant under the joint operation of the two NPPs. They establish the strategic role of the town of Paks in the economic life of the county; the NPP's electricity generation positively shifts the county's economic indicators.

Spatial planning aspects of the site and its vicinity

National scale

The National Spatial Plan (OTrT) is regulated by Act CXXXIX of 2018 on the spatial planning plan of Hungary and certain priority regions, and by Ministerial Decree 9/2019. (VI. 14.) MvM on the supplementary regulation of the preparation and application of spatial planning plans. The National Spatial Plan (OTrT) comprises the National Structural Plan, the National Zoning Plan, and the regulations applicable to them. The structural plan includes the delineation of national land use categories, as well as the spatial order of national transport infrastructure networks and individual structures of technical infrastructure. The regional zoning system of the national zoning plan is intended to ensure the differentiation of land use.

The National Structural Plan covering the 30-km radius of the Paks NPP is shown in *Figure 4.7.1.1-1*. The figure shows that the plan indicates not only the existing NPP, but also the planned new one. *Figure 4.7.1.1-2.* shows the national zoning plan maps of the OTrT's relevant to EIA, which indicate that within a 30-km radius of the NPP, there is a high proportion of forest and productive arable lands with excellent and good soil conditions; while natural areas – that is, elements of the ecological network – are also found over a large area. The floodway zone extends along the Danube and into the Gemenc area. There are a significant number of settlements, covering a considerable area, that fall into the categories of landscape protection, world heritage tentative sites, and water quality protection zones. Within a 30-kilometre radius, there are also a relatively large number of settlements affected by areas designated for national defence and military purposes.



National land use categories

- Forestry region
- Agricultural region
- Water management region
- Settlement region

Transport networks and individual structures

- Expressway (existing)
- Expressway (planned)
- Main road (existing)
- Main road (planned)
- Other national core network railway line (existing)
- National bicycle route
- National port (existing)

Energy networks and individual structures

- NPP (existing)
- NPP (planned)
- 400 kV transmission network overhead power line (existing)
- 400 kV transmission network overhead power line (planned)
- Natural gas transmission pipeline (existing)

Water structures

- Water structure of high priority (existing)
- Channel of national importance (existing)
- Channel of national importance (planned)
- Primary flood protection main defense line (existing)

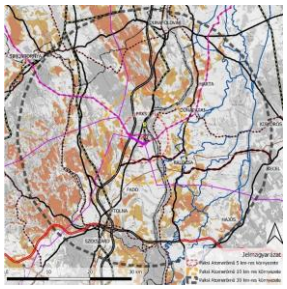
Base map elements

- County boundary
- Municipal administrative boundary

Figure 4.7.1.1-1. Extract from the National Structural Plan regarding the 30 km radius of the Paks NPP



Zone of forests (dark green) and areas proposed for afforestation (light green)



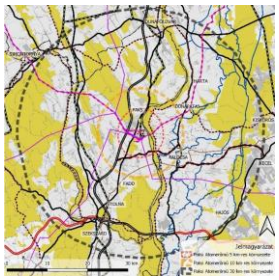
Arable lands with excellent (darker brown) and good (light brown) site conditions



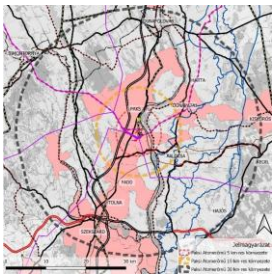
Zones of the National Ecological Network (green: core area, orange: ecological corridor, yellow: buffer zone)



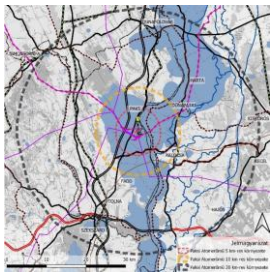
Floodway zone (dark blue)



Landscape protection area zone



Zone of settlements affected by world heritage tentative sites



Water quality protection area zone



Zone of settlements affected by national defence and military areas

Figure 4.7.1.1-2. Extracts from the National Zoning Plans (regional zones) within the 30 km radius of the Paks NPP

County scale

At this scale, the Spatial Planning Plan of Tolna County (Municipal Decree 8/2020. (X. 29.) of the General Assembly of Tolna County) and the Spatial Planning Plan of Bács-Kiskun County (Municipal Decree 2/2024. (II. 26.) of the General Assembly of Bács-Kiskun County) are relevant. Both county plans are in alignment with the 2018 National Spatial Plan. Accordingly, the structural elements, zoning classifications, and main findings of the spatial planning plans are summarized below.

Within the 30 km radius of the NPP, the proportion of forests and arable lands with excellent and good site conditions is high, and natural areas, as elements of the ecological network, also have a large surface extent. The floodway zone extends along the Danube and over the Gemenc area. The number and extent of settlements falling under the categories of landscape protection zones, world heritage tentative sites, and water quality protection zones are significant. Within the 30 km radius, there are several settlements affected by national defence and military areas. Among the supported target areas, the county spatial development plan classified almost the entire examined sub-region into the target areas of settlements supported for tourism development, the towns of Paks and Dunaföldvár for innovation and technological development, and the towns of Paks, Dunaföldvár, and Tolna for logistics development.

Based on the regional and specific zones of the Spatial Planning Plan of Bács-Kiskun County, it is worth highlighting that from a development perspective, the entire territory falls within the Danube Valley region and the new Danube bridge development zone. The latter is an area expected to exploit the spatial development attraction of the new Danube bridge. Furthermore, Kalocsa is classified into the zones of general tourism development, as well as health resorts and thermal baths. Ordas and Foktő belong to the zone of settlements affected by mineral raw material assets.

Local spatial planning aspects of the site and its vicinity

The 5 km radius of the NPP affects the administrative areas of 9 settlements, while its 10 km radius encompasses the administrative areas of an additional 7 settlements. The operation of the NPP, as well as the further extension of its service life, fundamentally does not involve any

territorial function changes or the construction of technical infrastructure elements that would need to be defined beyond the existing or planned elements already recorded within local spatial planning instruments. However, during further operation, other land uses might arise that are only indirectly connected to the NPP or not at all (e.g., a newly established solar park), or restrictions (e.g., utility or other infrastructure provision tied to temporary, transitional residential functions) that can be identified as sensitivity factors; thus, the details of the local spatial planning plans directly affected by the examined 5 km radius were briefly reviewed. Based on these, the following elements of the local spatial planning plans need to be highlighted: new infrastructure elements (Paks, Dunaszentgyörgy, Foktő, Gerjen), residential areas (Paks, Uszód, Dunaszentbenedek, Géderlak), areas for economic purposes (Paks, Gerjen), solar and wind power plants (Pusztahencse, Gerjen), and areas for defence purposes (Paks) have been designated.

Regarding the land uses and regulatory elements identified in the reviewed local spatial planning plans, it can be established that they do not contain any provisions to be taken into account with respect to the further extension of the NPP's service life. Based on the above, no exposure to any sensitivity factors has arisen.

4.7.1.2. Settlement environment characteristics of Paks town

The town of Paks is located in the central part of Hungary, in Tolna County, on the banks of the Danube. Thanks to its favourable geographical conditions (plains, good arable and forestry land, proximity to flowing water, etc.), it has been inhabited since prehistoric times. The administrative area of the settlement is 154.08 km^2.

Most important features of the urban development of Paks town

The settlement history of the Paks town over the past 200 years can be briefly summarized as follows:

- The settlement began to experience its golden age in the period between 1820 and 1830, as evidenced by numerous monuments and listed buildings. Characterized by a vibrant commercial life, the settlement – which at that time still existed in organic unity with the Danube – perhaps reached its peak at the turn of the 20th century and lasted until the Second World War.
- World War II (1939-1945) caused a significant decline in the town's life. Practically the entire Jewish bourgeois class, which had established the commercial character of the town, vanished. Regardless of this, the population of Paks had been continuously decreasing since World War I, and the strengthening of urbanization was also hindered by the lack of industrialization. Thus, a further slow stagnation and decline of the settlement of Paks can be observed in the period following World War II.
- In the 1950s and 1960s, the large village of Paks experienced the quiet everyday life of rural Hungary. Due to the relatively small number of industrial plants, jobs were scarce, leading nearly 1,000 people to commute daily between their workplace and the settlement. The population of the settlement continued to decrease, and the demographic population pyramid showed signs of aging.
- From the early 1970s, the planning, construction, and commissioning process of the NPP halted this unfavourable trend, as a result of which the town's population and the number of dwellings practically doubled between 1960 and 1980. The composition of the population also changed, with a skilled, young workforce appearing in the settlement.
- From the mid-1980s, the immigration of the young population resulted in a sharp increase in the number of children, which also modified the institutional and service demands. The number of nursery school places increased by 181%, kindergarten places by 141%, and primary school classrooms by 66%. Basic services also developed, as exemplified by a 106% expansion in retail floor space and a 328% rise in the catering network.

The development of the settlement over the past 40 years is therefore inseparable from the NPP. The Paks NPP has continuously played a role in the development of the town's life. The majority of the town's population is connected to the power plant, either directly or indirectly.

Land use of Paks town

Regarding the land use of Paks town, no significant changes occurred between 1990 and 2018, as established based on the Corine Land Cover 1990 and 2018, and the Copernicus Land Monitoring Service databases (*Table 4.7.1.2-1*).

Table 4.7.1.2-1. Land use data of the Paks town in 1990 and 2018

CLC code	CLC category	Area 1990 [ha]	Share 1990 [%]	Area 2018 [ha]	Share 2018 [%]	Change between 1990-2018 [ha]	Change between 1990-2018 [%]
112	Discontinuous urban fabric	564.4	3.7	604.0	3.9	39.6	7.0
121	Industrial or commercial units	466.3	3.0	520.3	3.4	54.0	11.6
122	Road and rail networks and associated land	0	0	202.0	1.3	202.0	
131	Mineral extraction sites	58.2	0.4	0	0	-58.2	no data
132	Dump sites	40.4	0.3	32.2	0.2	-8.2	-20.4
142	Sport and leisure facilities	32.6	0.2	66.7	0.4	34.1	104.7
Total artificial surfaces		1 161,9	7.5	1 425.2	9.2	263.2	22.7
211	Non-irrigated arable land	7 020.1	45.6	6 540.8	42.5	-479.3	-6.8
221	Vineyards	554.2	3.6	251.9	1.6	-302.3	-54.5
231	Pastures	516.5	3.4	702.5	4.6	186.0	36.0
242	Complex cultivation patterns	339.4	2.2	510.4	3.3	171.0	50.4
243	Land principally occupied by agriculture, with significant areas of natural vegetation	720.1	4.7	502.7	3.3	-217.4	-30.2
Total agricultural areas		9 150,3	59.4	8 508.3	55.2	-642.0	-7.0
311	Broad-leaved forest	2 378.9	15.4	2 971.7	19.3	592.8	24.9
312	Coniferous forest	484.0	3.1	440.9	2.9	-43.1	-8.9
313	Mixed forest	406.1	2.6	332.1	2.2	-74.0	-18.2
324	Transitional woodland-shrub	887.3	5.8	909.5	5.9	22.2	2.5
Total forests		4 156.2	27.0	4 654.3	30.2	498.0	12.0
321	Natural grasslands	304.5	2.0	282.0	1.8	-22.5	-7.4
411	Inland marshes	45.6	0.3	0	0	-45.6	n.a.
Total other natural, semi-natural and wetlands		350,1	2.3	282.0	1.8	-68.1	-19.5
511	Water courses	473.1	3.1	422.0	2.7	-51.1	-10.8
512	Water bodies	116.1	0.8	116.1	0.8	0.0	0.0
Total water bodies		589,2	3.8	538.1	3.5	-51.1	-8.7
	Total	15 407.8	100.0	15 407.8	100.0	–	–

Source: Corine Land Cover 1990 and 2018, Copernicus Land Monitoring Service.

The main directions of land use conversions aligned with national trends: the extent of artificial surfaces (residential areas, industrial and commercial units) increased by more than 260 ha, agricultural land (primarily the area of arable lands and vineyards) decreased by 640 ha, and the forest stock expanded by nearly 500 ha. Alongside these main directions, the drying out of wetlands also emerged (-45 ha). The proportions of the land use developed by 2018 – fundamentally agrarian in character, complemented by significant forest areas – remained unchanged. Both the proportion of broad-leaved forests (19.3%) and the total area under forestry management (30.2%) exceed the national values (15.4% and 23.5%).

General settlement environment characteristics

Physical geographical and spatial structural position of the town

With the establishment of the Paks NPP, Paks rapidly transformed into a town with a significant population, but also one that is predominantly single-functional. This applies not only to the transformation of the town's internal economy and, in part, its spatial structure, but also to its distinguished electricity generation position within Tolna County, the South Transdanubian region, and the country.

The town of Paks is the seat of the Paks District; within the district comprising 15 settlements, Dunaföldvár is the only other town besides the seat, while the remaining 13 settlements hold the status of a village. In principle, this situation would confer a prominent role on the center, but the settlement has been unable to fully utilize this role.

The establishment of the NPP also brought fundamental changes to the town's life in terms of work culture, as groups with high and specialized qualifications settled in the town, giving it unique character in this regard. Beyond meeting the power plant's educational needs locally, Paks was unable to dynamically strengthen its secondary school role within the settlement network.

Thanks to the power plant, the provision of local infrastructure in Paks has become qualitatively superior compared to that of towns of a similar size, and the development of basic infrastructure can be considered complete. However, beyond the commuting associated with its role as an employment hub, the town has not significantly expanded its inter-municipal network of relations through economic and spatial development.

In accordance with the special healthcare needs of the power plant, specialized medical outpatient care was expanded, but it was not possible to establish a municipal hospital. This indicates that a historically developed spatial structure and inter-municipal institutional system cannot be significantly transformed in a short period, even as a spin-off effect of a major industrial investment.

Demographic conditions and age distribution of Paks town

The population of Paks town decreased by nearly 1,600 people, or 8.2%, over the past 12 years, and the aging index also deteriorated significantly (from 105.9 to 154.7); meaning that the number of people over 65 is already 1.5 times higher than the number of those under 14, which is slightly higher than the national value (145). The proportion of women within the population remains stable at 51%. The population decline is largely due to the net migration balance (-1,832 people since 2012) rather than natural decrease (532 people since 2012). In terms of population density, the indicator for Paks (116 people/km^2), despite the continuous decline, is 13% higher than the national average (102.55 people/km^2 in 2024) and more than double the average of Tolna County (55.24 people/km^2).

Technical infrastructure and institutional provision

The decline in the resident population over the past 20-25 years was not followed by the number of dwellings; in fact, 470 new dwellings were built between 2003 and 2024. The operation of the NPP requires a high-level, large-scale infrastructure provision and service sector. The housing stock has been fully connected to the public drinking water pipeline network for more than 10 years, and 99.5% of the dwellings are connected to the public sewerage network. Wastewater treatment is provided by a dedicated wastewater treatment plant. Similarly to the water utility network, electricity supply is comprehensive. The proportion of dwellings using natural gas for residential heating is 47%. District heating supplied from the waste heat of the power plant primarily serves the Kishegy residential area (comprising 31% of the total housing stock).

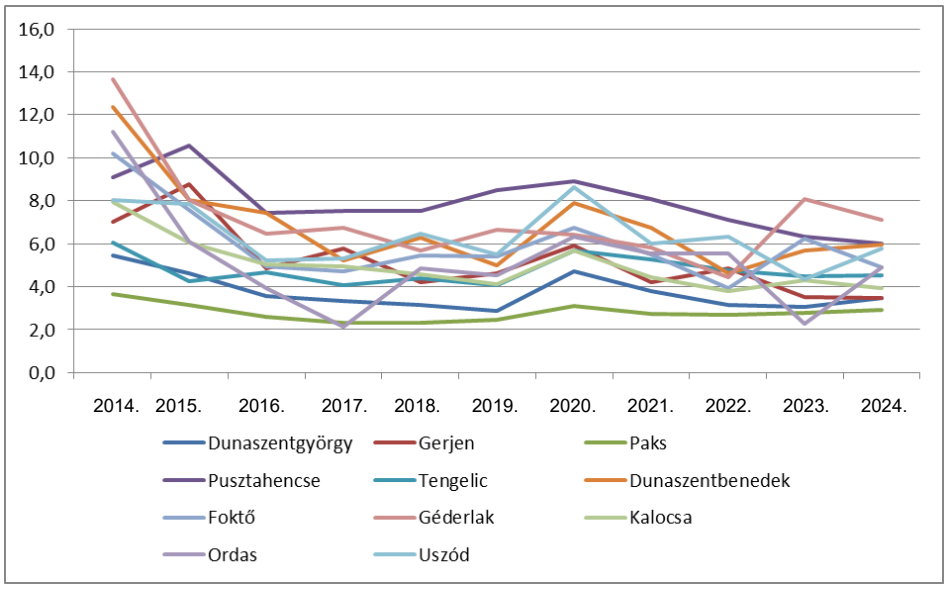
The existing public institutions, nursery schools, and primary schools satisfy current demands. Six primary schools and five secondary schools operate in Paks, including an institutional facility for vocational training in energy. Healthcare services are provided by outpatient clinics and specialist care centres; the town does not possess a hospital, but it does have an ambulance station and a medical centre.

Major economic characteristics

In 2024, the total number of registered businesses in the town was 3,256. Over the past 10 years, this number increased by nearly 10%. Approximately a quarter of these are classified as corporate enterprises. While 97% of the businesses employ fewer than 10 people, four of the six companies in Tolna County that employ more than 500 people operate in Paks.

The construction industry and the service sector are growing dynamically; manufacturing, trade, motor vehicle repair, as well as information and communication decreased to a lesser extent, while the financial and insurance sector experienced a more significant decline.

The relative unemployment rate (which shows registered jobseekers as a percentage of the working-age population) is much lower in Paks (2.91% in 2024) than in the surrounding settlements due to the labour absorption capacity of the NPP and related support companies (*Figure 4.7.1.2-1.*), which is also more moderate than the national (3.54%) and Tolna County averages (4.08%). In Paks, 62% of the registered jobseekers were over 35 years old, and 9% were career starters in 2024.



Source: Own elaboration based on Hungarian Central Statistical Office (HCSO) data

Figure 4.7.1.2-1. Trends in the unemployment rate in the Paks town and the surrounding settlements

Protected assets and assets to be protected (elements of cultural heritage, green spaces)

Pursuant to Act LXIV of 2001 on the protection of cultural heritage, "*the elements of cultural heritage comprise the archaeological heritage, the elements of military history heritage that can be researched using archaeological methods, monument values, national memorial sites, priority national memorial sites and their townscape protection environments, as well as cultural property".* The protected assets are the following:

- No World Heritage sites are located within the examined settlements. However, World Heritage tentative sites[9] can be found within the administrative areas of Paks, Dunaszentgyörgy, and Fadd ('Frontiers of the Roman Empire – The Danube Limes in Hungary'), as well as Györköny, Uszód, and Dunapataj ('Network of Hungarian Regional Houses').
- Within the examined region, monuments are typically located within the inner areas of the settlements. Based on nationally available and local databases[10], a total of 55 monuments

[9] Pursuant to Ministerial Decree 27/2015. (VI. 2.) MvM on the Tentative List of World Heritage Sites, and Act CXXXIX of 2018 on the Spatial Planning Plan of Hungary and certain priority regions.

[10] Local Built Heritage Conservation Register, HÉSZ (Local Building Regulations) annexes of the municipalities, and the muemlekem.hu website.

of national importance are located within the 10 km radius of the NPP across 8 settlements, of which a total of 24 (from 5 settlements) lie within the 5 km radius. These are mainly sacred monuments and residential houses. Their location is shown in *Figure 4.7.1.2-2*.

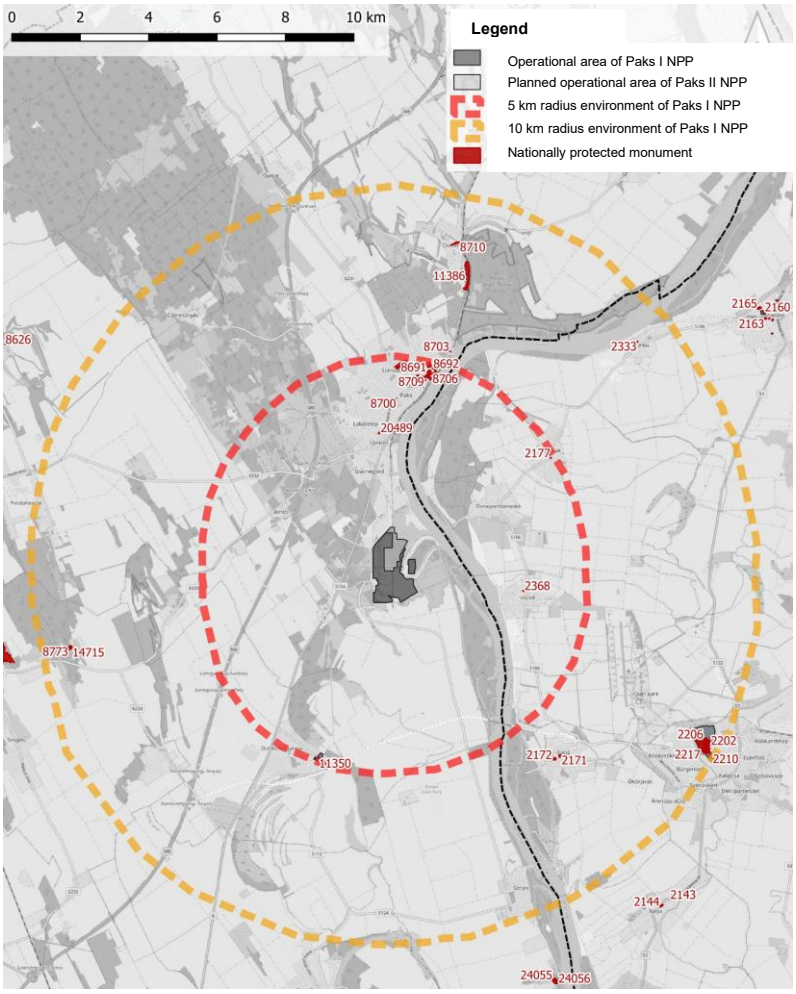


Figure 4.7.1.2-2. Nationally protected monuments within the 5 km and 10 km Radiuses of the Paks NPP

- Within the 5 km radius of the NPP, there are 70 locally protected structures in Paks, 39 in Dunaszentgyörgy, 4 in Uszód, 39 in Dunaszentbenedek, and 37 in Géderlak (totalling 189 structures). These are typically residential buildings, religious/sacred structures, and monuments.
- Within the 10 km radius of the NPP, there is a total of 336 registered archaeological sites (*Figure 4.7.1.2-3.*).
- Green space elements can also be considered as protected values of the settlement environment, which within the 5 km radius of the NPP are typically located within the inner area of Paks. These include the loess wall of Paks, Ürgemező, Táncsics Park, the old Calvinist cemetery, the Virág Street cemetery, the sports grounds of the NPP, institutional and residential green spaces, as well as the cemeteries of Uszód and Dunaszentbenedek.

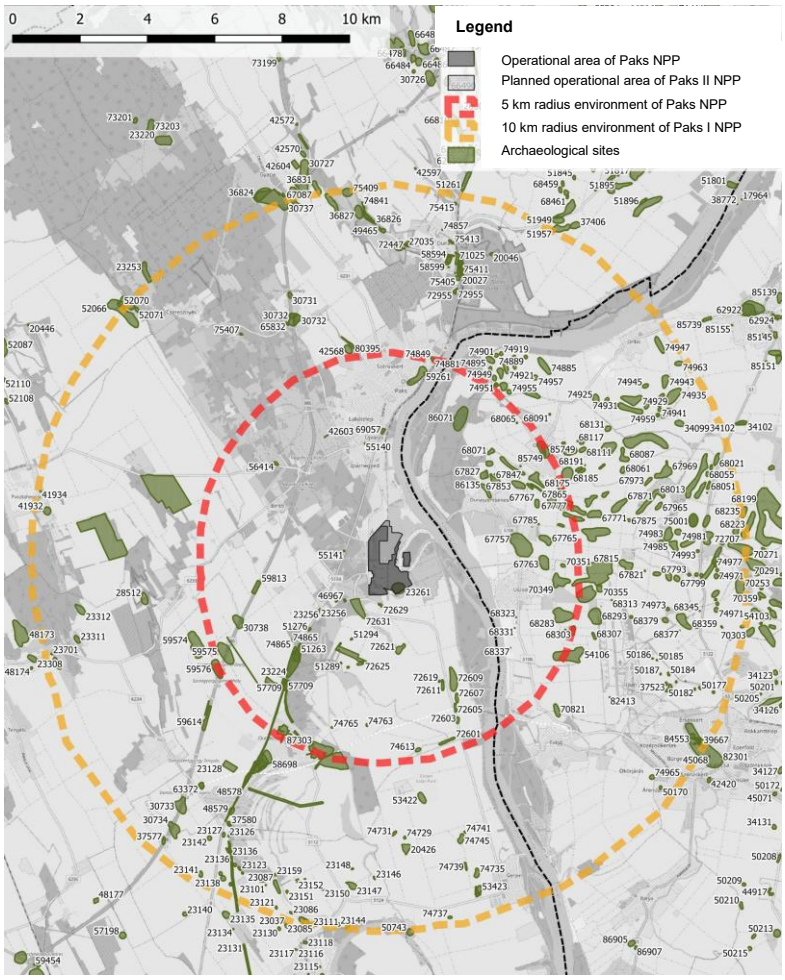


Figure 4.7.1.2-3. Archaeological sites within the 5 and 10 km radius of the Paks NPP

4.7.2. Impacts on the settlement environment

The expected impacts were investigated from the perspective of the independent operation of the Paks NPP and its joint operation with the Paks II NPP. The decommissioning process, however, must be addressed in a separate environmental impact assessment.

From a settlement environment perspective, the impacts of normal operation are identical to the characteristics of the baseline condition, given that the presence and operation of the NPP have shaped the current land use structure and characteristics of the settlement environment.

4.7.2.1. Impacts of the independent operation of the Paks NPP

The impacts of the independent operation of the Paks NPP can be compared to those of its decommissioning; in other words, the question is what changes can be expected in the settlement environment if the Paks NPP is shut down and no further power generation takes place at the plant. Due to the special nature of the NPP's decommissioning and abandonment, the facility itself and a significant portion of its associated structures are expected to remain in place for the long term. However, the consequences of this do not need to be investigated in detail, as they must be addressed as part of the environmental licensing process for the decommissioning. With regard to environmental impacts, the characteristics assessed and presented as part of the baseline condition are taken into account.

Land-use and spatial planning aspects of the site and its surroundings

Based on the review of spatial and master plans at the national, county, and municipal levels, it can be stated that no significant changes are expected regarding land-use zones and spatial

structure elements as a result of the SSLE of the plant. The previously defined land-use development objectives, which take the existence of the NPP into account, are aligned with the long-term or planned elements also identified in the land-use and spatial planning documents. Individual planned and advanced developments (e.g., where regulatory permits are available or construction is already in progress), or those that have already been implemented will trigger the implementation of additional land-use planning elements (e.g., in the case of areas designated for development – residential, commercial, or other special-use – or special-use areas not intended for development). It cannot be ruled out that a further service life extension of the NPP may indirectly influence the actual implementation of these additional developments.

Expected changes in the settlement environment of the Paks town

Among the general settlement environment characteristics of the town of Paks, its physiographic and spatial structural position is not expected to change as a result of the SSLE. No change is expected in these characteristics even if energy production ceases at the facility. Such a change can only be estimated if energy production at the Paks NPP is shut down and the new units of Paks II NPP do not commission either. In this case, if no new investment arrives in the municipality to replace employment, emigration and economic decline can be expected. This could bring changes not only to economic but also to social characteristics. Emigration could primarily affect the younger, more highly skilled population, which may also result in adverse changes to demographic conditions (total population size, age composition, educational levels). If the SSLE is implemented, these issues will not arise, and no significant changes in these characteristics are expected. In the event of the SSLE, therefore, a situation similar to the current one is expected in both economic and social terms, and the impact will be neutral.

Likewise, no change is expected in the characteristics of technical and other infrastructure, nor in institutional provision; these can be maintained in their current state thanks to the fact that the facility remains definitive from an economic perspective as well.

Regardless of the NPP, the characteristics of the transport networks have changed more significantly with the completion of the new Danube Bridge (Tomori Pál Bridge between Kalocsa and Paks), which is also expected to have an economic stimulating effect on the eastern side of the Danube.

The good relationship between the NPP and the town is not expected to change and will remain unbroken during the period of the SSLE. The effect is ameliorative, and the favourable condition from the town's perspective will remain stable. (Decommissioning could create a less favourable situation due to the loss of revenues and subsidies.)

Impacts on the condition of protected assets

In the settlement environment, both in the wider and narrower surroundings of the power plant, the condition of protected assets and those to be protected (built environment, green spaces, monuments as part of cultural heritage, archaeological remains) is not expected to change in connection with the SSLE of the plant, and the possibilities for their preservation and maintenance will remain unaltered. The vulnerability of these assets is not affected by the continued operation. (In the event of the decommissioning of the industrial facility and the cessation of its economic stimulating effect, a narrowing of the funds available for maintenance is expected, which may also cause a decrease in such preservation options.) The continued operation is therefore neutral also from the perspective of protected assets. (Compared to decommissioning, however, a more favourable situation is expected).

From the perspective of the settlement environment, the impact area continues to be considered primarily within the administrative area of Paks (inner parts of the city, contiguous, urban, industrial areas).

4.7.2.2. Combined impacts of nuclear facilities currently operating and planned at the site

Spatial and settlement planning aspects of the site and its vicinity

Based on the content of the development plans reviewed at the national, county, and municipal levels, it cannot be unequivocally ruled out that changes will occur in land use units and spatial structural elements as a result of the joint operation. However, the regional development goals previously established due to the existence of the Paks NPP and the construction of the new NPP are fundamentally aligned with the long-term or planned elements designated in the spatial and settlement planning plans. The implementation of further spatial planning elements directly expected as a result of certain prepared, advanced, or already implemented developments is ongoing. The spatial scope of these could even expand in connection with the construction and operation of the new units (e.g., new residential areas, infrastructure).

Just as it was established in connection with the independent operation of the Paks NPP, it is likely in the long term that the actual implementation of these further developments may be indirectly influenced by the joint operation. For instance, an expansion in labour demand to an extent that necessitates involving labour from more distant areas cannot be ruled out, which could also entail infrastructure development, and thus, changes in the spatial structure (providing additional justification for the implementation of the secondary main road connection planned in the long term between Sárszentlőrinc and Tamási).

The placement of the alternative warm-water channel section and the peak cooling system affects the NPP industrial-economic zone designated as Gip-M/PI, the water management zone designated as V-6 (fishing ponds), the water management zone designated as V-3 (flood protection dyke), and a narrow strip of protective forest zone designated as Ev. Due to this, a minimal modification of the spatial planning plan becomes necessary (annexing the area affected by the intervention, which is currently not designated as an industrial zone, to the industrial zone).

Expected changes in the settlement environment characteristics of Paks town

Among the general settlement environment characteristics of Paks town, its physiographic position will not change during the joint operation either. However, the spatial structural position may improve in parallel with the joint operation of the two NPPs and the economic strengthening of the town. (That is, the combined operation of the two power plants, along with the emergence of the necessary skilled labour and the additional developments required to meet their needs – from housing to recreation – can bring further economic strengthening to the municipality.)

This finding is also confirmed by the Regional Development Program of Tolna County (2021-2030), which, discussing the construction of Paks II NPP, states: *”The development will have significant social, economic, infrastructural, and environmental impacts affecting a large area.” … „The Paks II project will make its impact felt not only in Paks but will also have a significant impact on the lives of municipalities located within accessible distance from there. The goal is for municipalities to be prepared for the expected population growth and to profit as much as possible from the investment. To achieve these goals, the development of public institutions and linear infrastructure is necessary. The development of public institutions and the raising of their service standards will also improve the service provided to those already living in the municipality.”*

If the two NPPs operate jointly, these impacts could be even more significant. The new Danube Bridge enables the movement of labour from the direction of Kalocsa as well, as the travel time between the two towns is reduced to approximately 15 minutes. Therefore, the development and the continued operation entail a favourable, ameliorative effect extending to other counties and districts.

The demographic situation will also improve, as the joint operation of the two power plants definitely implies an additional labour requirement. Although this might not double the number of employees at the two power plants, provision must definitely be ensured in the area for several hundred or up to a thousand skilled, expectedly mostly young workers and their families. This can be covered partly through immigration and partly from the surrounding municipalities. A rejuvenation is expected not only in numbers but also in the age composition. Along with the

commissioning of Paks IINPP, the continued operation provides an opportunity for the emergence and training of young professionals. The county program also sets the development of training and research as a goal, which can be linked to the power plants.

The SSLE and the joint operation of the two power plants could bring about beneficial changes in both economic and social conditions, and the impact can be considered improving.

Regarding the characteristics of technical and other infrastructure, as well as institutional provision, it is also true that the emergence of additional labour can bring favourable impacts and strengthen the possibilities for their implementation and expansion. The joint operation can further reinforce the good relationship between the NPPs and the town, and the favourable condition from the town's perspective can improve even further.

Impacts on the condition of protected assets

As established regarding the impacts of independent operation, the condition of protected assets and those to be protected within the settlement environment – both in the wider and narrower surroundings of the power plant (built environment, green spaces, monuments as part of cultural heritage, archaeological remains) – is not expected to change in connection with the further operation of the Paks NPP; the possibilities for their preservation and maintenance will remain unaltered, and the vulnerability of these assets will not increase.

The built heritage cannot be considered a receptor directly as a result of the joint operation either. Rather, the implementation of other regional development aspirations linked to the joint operation (e.g., residential, economic, and other special zones designated for long-term development) may entail consequences where the identification of the built heritage as a receptor cannot be unequivocally ruled out (e.g., the involvement of archaeological sites through related activities involving earthworks). The extent and significance of this also depend on the geographical location of other developments directly or indirectly linked to the joint operation, as well as on other likely impacts of their implementation, but are fundamentally not tied to the current activity.

4.7.2.3. Emergency event and transboundary impacts

Conventional emergency events are not expected to have any detectable impacts on the settlement environment. From a settlement environment perspective – taking into account the distance to the national border – no transboundary impacts are to be expected.

4.8. Management of non-radioactive waste

Based on the available operational data and environmental reports regarding the waste management system of MVM Paksi Atomerőmá Zrt., it can be established that the current non-radioactive waste management system operating at the site is proven in practice to function in a lawful, controlled, and reliable manner, and it is also capable of handling the additional waste streams emerging during the preparation and implementation periods associated with the SSLE without any compliance risk. Waste management begins near the point of generation with segregated collection by fractions, then proceeds through the on-site temporary storage and operational collection point infrastructure to the documented transfer to a licensed operator, which ensures the full traceability of waste streams. The operational logic of the system is not built on on-site accumulation, but on ensuring that waste, following its generation, is sent for recovery or disposal in an organized, controlled, and verifiable manner. A particularly important element of this is that the on-site temporary storage of hazardous waste is limited in time; for hazardous waste, storage for longer than one year is not permitted. Therefore, when evaluating waste management performance, it is an essential criterion that the volumes recovered or disposed of in a given year may partly include batches generated in previous years, and a portion of the waste generated in a given year may actually be transferred and treated at the beginning of the following year. This characteristic is a natural consequence of the on-site waste management process and does not indicate operational instability in the system; rather, it reflects a regulated operation

adapted to operator capacities, transport scheduling, as well as the qualification and preparation processes of waste streams.

Based on the quantitative data from the operational period between 2014 and 2023, which represents the phase of normal operation, the volume of industrial waste remains consistently high. However, the trends in waste generation within and between years can fundamentally be explained by the scheduling of major maintenance cycles, reconstructions, and technological interventions. During this period, the annual quantity of non-hazardous industrial waste averaged approximately 1,180 tons/year, typically fluctuating within a range of 700 to 2,200 tons/year, while the annual quantity of hazardous industrial waste averaged around 390 to 400 tons/year. Thus, during the baseline period, the site's waste management system demonstrated its suitability in an operating environment where complex waste streams involving multiple fractions had to be managed on an annual scale of up to thousands of tons. One of the most critical key performance indicators of the system is that the vast majority of the generated waste was treated each year, meaning it left the site in a verifiable manner through recovery or disposal, and long-term accumulation was not typical. In the case of non-hazardous fractions, the recovery rate ranged between 60% and 90% during most of the assessment period, and in certain years, recovery approached 90%, indicating the efficiency of selective collection, the consistent separation of recoverable material streams, and a practice aligned with the waste hierarchy. In the case of hazardous waste, operations can be evaluated from a risk management perspective, as environmental risks, packaging and labelling discipline, storage conditions, and documentation are of primary importance for these waste streams. The management of hazardous waste at the site takes place in a controlled manner under segregated collection and storage conditions, and due to the time limits integrated into the system's operation, hazardous waste cannot accumulate in an unregulated manner, which is essential for environmental safety.

The 2023 data, used to present the current baseline conditions, specifically substantiate the operability of the system and demonstrate that the vast majority of waste streams were treated during that year. In 2023, the quantity of non-radioactive waste generated was 1,011.522 tons, while the volume disposed of or recovered amounted to 990.554 tons. This indicates that the treatment rate relative to generation can be considered near-comprehensive, leaving only a limited quantity at the site as closing inventory for the subsequent period. Based on the environmental reports, the recovery rate in 2023 was above 70%, which is consistent with the fact that a significant portion of the non-hazardous fractions is recyclable, and the on-site selective collection, pre-treatment, and transfer practices effectively support this. At the same time, when interpreting the 2023 data, the operational characteristics of on-site temporary storage must be taken into account, particularly in the case of hazardous waste. Since hazardous waste may be stored for a maximum of one year, the quantities treated in 2023 may partially include batches generated in 2022. Conversely, a portion of the batches generated in 2023 may carry over to early 2024 due to the scheduling of transport and operator acceptance. This phenomenon is an inherent part of the waste management system's operations and does not diminish compliance, as the essence of the process lies in documented transfer and adherence to storage time limits. Based on the volume of waste generated in 2023, the scale of nearly one thousand tons is primarily attributable to technology-derived waste streams from normal operations, planned preventive maintenance and periodic major overhauls, as well as operations related to the cleaning of technological systems and water treatment. Meanwhile, construction and minor modification works, along with site maintenance and operational activities, contributed to the volumes in a complementary manner. Overall, the 2023 treatment data, the high recovery rate, and the absence of accumulation support that the site system operates stably in its current state and manages waste streams in an appropriate, controlled manner.

When assessing the expected impacts of activities related to the SSLE, it is important to note that the projected volumes for the preparation period from 2026 to 2037 and the implementation period from 2038 and 2057 do not replace the total industrial waste generation but represent the additional waste streams compared to normal operation. Accordingly, they are added to the industrial waste volumes typical of the base period, thereby determining the total waste generation for the given years. According to the forecast for the preparatory period, the total amount of additional waste generated is typically in the range of 420-560 tons/year. However, peak values

are expected in 2031 and 2032, when the additional waste could reach 700-760 tons/year. The composition of the additional waste during this period is predominantly non-hazardous, with the proportion expected to be 80-90%, while the volume of hazardous waste typically ranges from 20 to 90 tons/year. In terms of volume, this is significant because, compared to the 1000-2000 tons/year operating range during the base period, the annual surplus typically amounts to 260-760 tons/year, which represents an increase of approximately 13-76%, depending on whether the normal operating baseline in a given year is closer to the lower or upper end of the baseline range, and which phase of the preparation program is the most intensive.

The reason for the increase is typically not a continuous, uncontrolled load growth, but rather that, alongside the maintenance of normal operations, targeted technical interventions that involve waste generation take place in parallel and in a periodically concentrated manner. This includes reconstruction and modernization projects, partial replacements of certain equipment, renovations of auxiliary systems, condition assessments and technological cleanings, as well as related construction and renovation work. These activities typically generate large volumes of non-hazardous fractions, characteristically scrap metals, inert construction and demolition waste, packaging materials, and other waste originating from plant maintenance, while the quantity of hazardous fractions remains overall minor. Based on data from the baseline period, the on-site system has previously handled annual waste streams in the order of thousands of tons, therefore, the management of the additional waste streams between 2026 and 2037 can be handled technically and organizationally within the existing collection, logistics, and documentation framework, and the maintenance of lawful, controlled operations can be realistically ensured. The predictable nature of the waste streams and the fact that the surplus consists predominantly of non-hazardous fractions also enhance manageability, as recovery options and treatment capacities are typically more widely available for non-hazardous fractions.

The additional waste load during the implementation period from 2038 to 2057 is expected to be more moderate and steady in most years, with forecasts typically ranging from 100 to 350 tons/year, representing a general increase of 5-35% compared to the 1000-2000 tons/year range during the base period. Within this, the volume of non-hazardous fractions is typically 50-300 tons/year, while hazardous fractions remain in the range of a few tons to a few tens of tons/year in most years, and their proportion generally ranges between 5-20%. The picture for the implementation period is therefore generally more favourable than that of the preparatory phase, because the surplus is smaller and is typically associated with waste generation patterns similar to those of normal operations, which the on-site system already managed well during the baseline period. However, during the implementation period, a significant spike in volume is expected in two years – 2047 and 2048 – when the total amount of additional waste could reach approximately 1800 tons/year, with more than 95% of this being hazardous waste, primarily demolition debris containing asbestos. This surge is significant from an interpretive standpoint because it does not indicate an increase in load resulting from normal operations, but rather is the consequence of a one-time, concentrated demolition and reconstruction program during which large quantities of asbestos-containing structures may be removed. During these peak years, the volume of asbestos-containing waste is estimated to be approximately 1600-1700 tons, which accounts for the predominance of the hazardous fraction. Following these peak years, the volume of excess waste returns to the range of a few tens to hundreds of thousands of kg per year; in other words, the temporary predominance of the hazardous fraction is not a lasting trend, but rather a well-defined, manageable temporary phenomenon. In terms of the adequacy of the on-site waste management system, this is significant because the system must periodically give special attention to a high-volume waste stream that is hazardous and requires specific handling conditions. At the same time, due to its temporary and programable nature, the necessary capacities, transportation, and transfers can be scheduled in advance, and lawful management can be ensured.

In terms of the nature of waste generation, based on both the baseline period and projections, the dominant non-hazardous waste streams include metal waste – particularly iron and steel scrap – as well as inert construction and demolition waste, packaging waste, green waste, and cable waste. Iron and steel scrap account for a significant proportion of the non-hazardous waste,

and on its own can account for more than 50% of the total non-hazardous waste, 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, which is typically highly recoverable. Hazardous fractions are typically dominated by waste associated with technological operation and maintenance, particularly waste oils and oily water, hazardous aqueous liquid waste, contaminated filters and absorbents, as well as certain chemical waste streams. In normal years, asbestos-containing waste typically accounts for a minor proportion of the hazardous fraction, representing approximately 4-5%. However, due to the demolition program expected in 2047-2048, it will temporarily become a dominant component. In terms of recycling performance, the data paint a generally positive picture. With the recovery rate for non-hazardous fractions remaining high for several years, and environmental reports indicating that the recovery rate remained above 70% in 2023 as well, which confirms the consistent separation and transfer of the recoverable portion of on-site waste streams.

Based on the assessment of environmental impacts related to waste management, the impacts are typically minor, intermittent, and localized, primarily associated with material handling, collection, and storage operations within the site, as well as with transportation following removal from the site. During normal operations, typical impacts include noise from internal logistics, the potential for dust generation, and periodic increases in traffic volume. However, with appropriate organizational measures in place, these do not cause lasting changes to environmental conditions. The area affected by transportation is typically limited to a radius of 300-500 metres from the site's gate. During the period between 2047 and 2048, when large quantities of asbestos-containing waste are being transported, the impact area outside the site may temporarily extend up to a few kilometres along major transportation routes. However, this will primarily manifest as a temporary and minor increase in traffic-related noise and air pollution, and is expected to represent a negligible increase relative to the power plant's total road traffic. Therefore, it will not result in environmental impacts posing a lasting or health-related risk. Based on the investigations, no transboundary environmental impact is expected.

In summary of the above assessment criteria, 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. During the base period from 2014 to 2023, the system managed annual waste volumes in the order of thousands of tons, while the vast majority of the generated waste was documented as having been recovered or disposed of each year, and the recovery rate was particularly favourable in several years. The numerical data for 2023, which reflects the current situation, also supports this, as 990.554 tons of waste was treated out of 1011.522 tons generated, and the recovery rate exceeded 70%.

In the case of hazardous waste, compliance with storage time limits and documented handover provide a system-wide guarantee that waste streams do not accumulate and that environmental risks remain under control. Based on the expected volume and composition of additional waste streams during the preparation and implementation period associated with the SSLE, the load is largely predictable and time-limited; the surplus is moderate in most years, and even in peak years, it is clearly identifiable and linked to one-time interventions.

Based on all the above, it can be reasonably stated that the current waste management system not only operates appropriately under current operational conditions, but will also be capable of maintaining lawful, controlled, traceable, and environmentally safe operations under the additional waste load emerging during the preparation and implementation of the SSLE. Furthermore, the management of waste does not pose an environmental load or risk of a magnitude that would limit the feasibility of the planned activity.

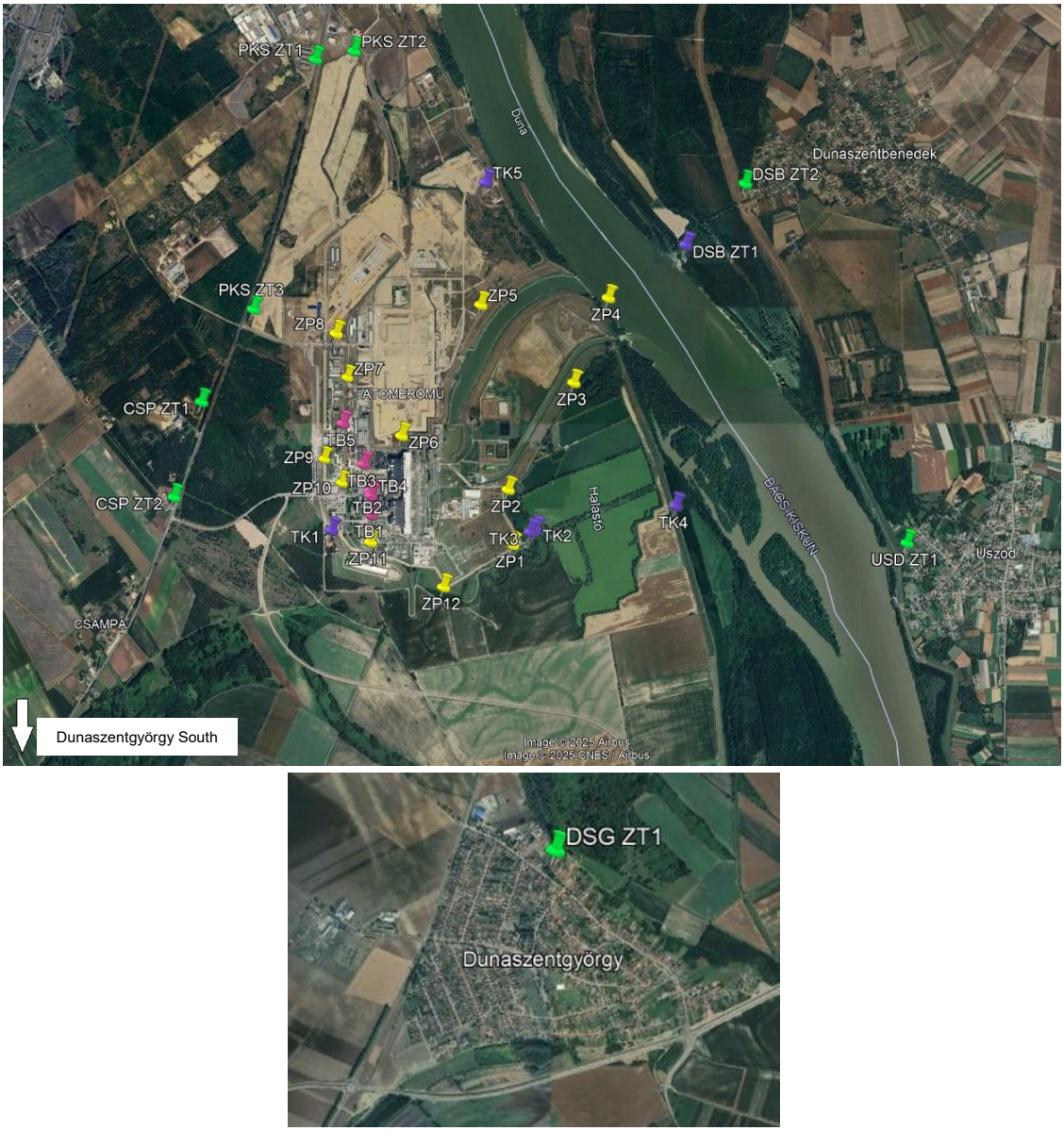
4.9. Impacts on noise and vibration conditions

As an industrial plant, the Paks NPP causes noise pollution in its vicinity and also generates vehicle traffic on access routes. Regarding the operation of the NPP, the current environmental noise situation is presented through baseline noise measurements, and the baseline values for road traffic are presented through noise calculations based on traffic data.

The assessment of the impacts of noise emissions resulting from the independent operation of the Paks NPP and its joint operation with the Paks II NPP, the analysis of the impact of a noise-relevant emergency event scenario, and the delineation of noise-affected areas using a calculation method based on noise modelling are presented. During the investigations, archived noise exposure data and noise protection-related results from the period since the Paks NPP began operations were also processed.

4.9.1. Baseline noise conditions, background noise load induced by operational and road traffic

The assessment of the operational noise exposure and background noise load of the Paks NPP was conducted within the assumed direct impact area, in the nearest area requiring protection, and at the nearest facilities requiring protection, within a radius of approximately 3 km measured from the centre of the Paks NPP site. The noise measurement points are shown in *Figure 4.9.1-1*.



Legend:

PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise exposure point, ZP: noise measurement point at the property boundary, TK: reference point outside the Paks NPP site, TB: reference point within the Paks NPP site.

Figure 4.9.1-1. Overview map of noise measurement points

Based on on-site investigations, the operational noise load of the Paks NPP in the surrounding residential areas is low. Therefore, it cannot be perceived or measured independently from the background noise. There are no other significant industrial facilities in the vicinity besides the Paks NPP. Therefore, when determining the plant's background noise load, the noise levels with a 95% frequency can be taken into account, as shown in *Table 4.9.1-1*.

Table 4.9.1-1. Operational background loads that can be used as a reference

Settlement (zone)	Measurement point code	Operational background load [dB]		Basis for determining the background load [dB]
		Daytime	Nighttime	
Dunaszentbenedek (Lf)	DSB ZT2	28.8	29.7	$L_{AF95\%}$
Uszód (Lf)	USD ZT1	24.1	24.7	$L_{AF95\%}$
Dunaszentgyörgy (Lf)	DSG ZT1	26.9	25.9	$L_{AF95\%}$
Paks (Vi-M/10, K-Eü); Paks-Csámpa (Lf)	CSP ZT2 HT	40.1	33.1	$L_{AF95\%}$
Paks (Economic and other zones)	TK4 HT	29.4	35.0	$L_{AF95\%}$

Note: Lf – rural residential zone; Vi-M/10 – institutional zone (educational and training centre, commercial, service, accommodation, workers' hostel, office, research and development, sports use); K-Eü – healthcare centre area.

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

With regard to baseline road traffic noise levels (background load) at the reference points requiring protection along the M6 motorway, noise levels remain below the limit values at all monitoring 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 dB at the test points during daytime and/or nighttime hours.

4.9.2. Current impacts of normal operation of the Paks NPP

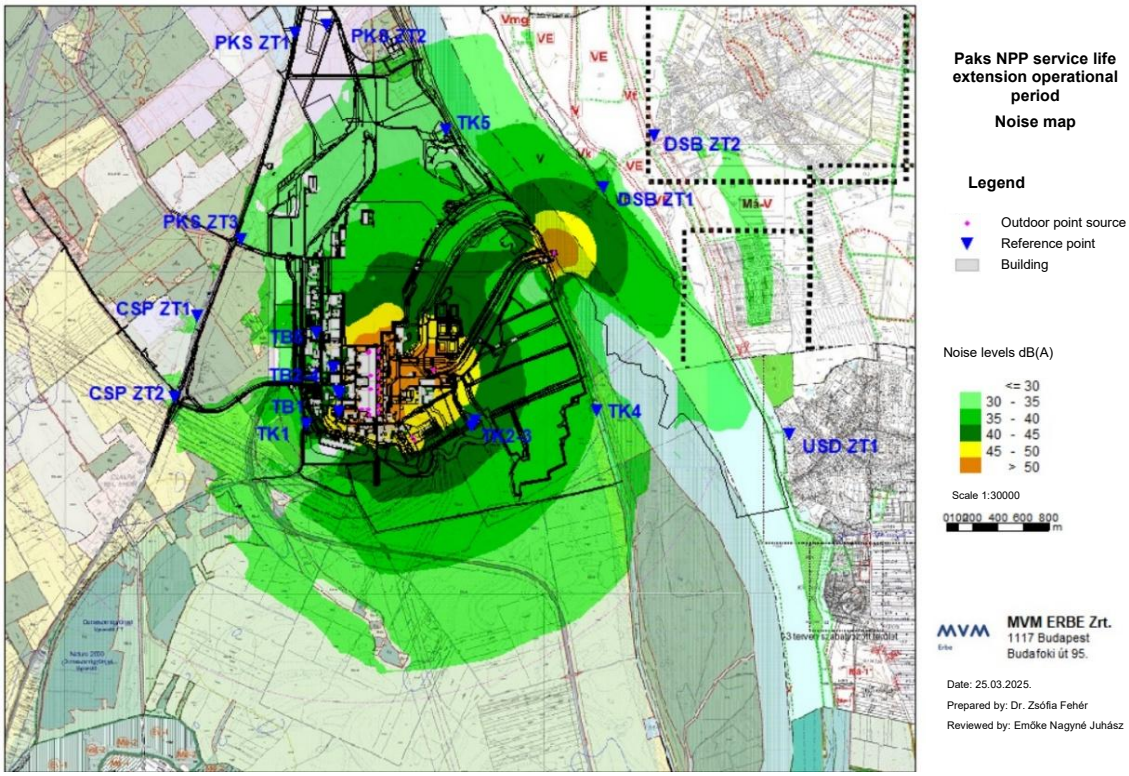
From a noise assessment perspective, the impact factor to be evaluated during normal operation of a NPP is the noise emissions from the noise sources causing the noise exposure. The impacts in terms of direct noise occur within the plant site. There are 8 steam turbines operating in the turbine halls of the main buildings of the Paks NPP. The equipment of the transformer station, located in the eastern part of the building, is connected to these units. The refrigerator building is located next to the central section of the main building. The plant's operations include two water intake structures with submersible pumps at the inner end of the cold-water channel. The 12-bar fire water pump station and two pump stations are located on the eastern boundary of the plant site. The outdoor transformer station and the network control room are located on the south-eastern edge of the site. The high-pressure compressor is located in the building on the southern edge of the plant site. The cooling water extracted from the Danube via the cold-water channel and subsequently utilized is discharged into the warm-water channel through the level-retaining weir. The water from the warm-water channel is discharged into the Danube. The forces resulting from the flow velocity are absorbed by the energy-dissipating structure prior to discharged back into the river. Activities carried out in the maintenance workshops on-site are essential for the continuous operation of the NPP. The hydrogen building – which currently functions as a low-pressure compressor station – is located in the southeastern region of the plant.

The actual noise exposure from the Paks NPP at locations requiring protection from distant noise (where the noise exposure from the plant is already so low that it cannot be measured on-site) was determined based on a noise model derived from measurement points located near the plant's operational noise sources. Based on the noise modelling, it can be concluded that the current environmental noise exposure from the Paks NPP remains below the prescribed noise

exposure limit (*Table 4.9.2-1.*). The noise emissions from the Paks NPP are illustrated by the noise map shown in *Figure 4.9.2-1*.

Table 4.9.2-1: Operational noise exposure of the Paks NPP and the noise exposure limits

Key	Noise-sensitive receptor, noise-sensitive area	Limit Value [dB] Daytime / Night-time	Noise Exposure [dB] Daytime/Night-time
PKS ZT1	Workers' hostel under construction in the Vi-M/10 mixed institutional zone in Paks	55/45	27/27
PKS ZT2	Special healthcare centre zone in Paks, plot number: 8802/34	45/35	28/28
PKS ZT3	Residential building near the northern entrance of the Paks NPP, plot number: 057/11	60/50	31/31
CSP ZT1	22 Csámpapuszta, Csámpai Fenyvestanya, Paks, plot number: 0292/2	50/40	32/32
CSP ZT2	Csámpa Village Hall, 33 Csámpapuszta (2), Paks, plot number: 0191/23	50/40	30/30
DSG ZT1	Residential Building, 22 Béke Square, Dunaszentgyörgy, plot number: 112/1	50/40	5/5
DSB ZT2	Residential Building, 3 Zöldfa Street, Dunaszentbenedek, plot number: 581/2	50/40	27/27
USD ZT1	Residential Building, 15 Béke Street, Uszód, plot number: 044	50/40	28/28
TB4	Medical Clinic, Paks NPP, Paks	60/50	46/46
TB5	Fire Station, Paks NPP, Paks	60/50	42/42



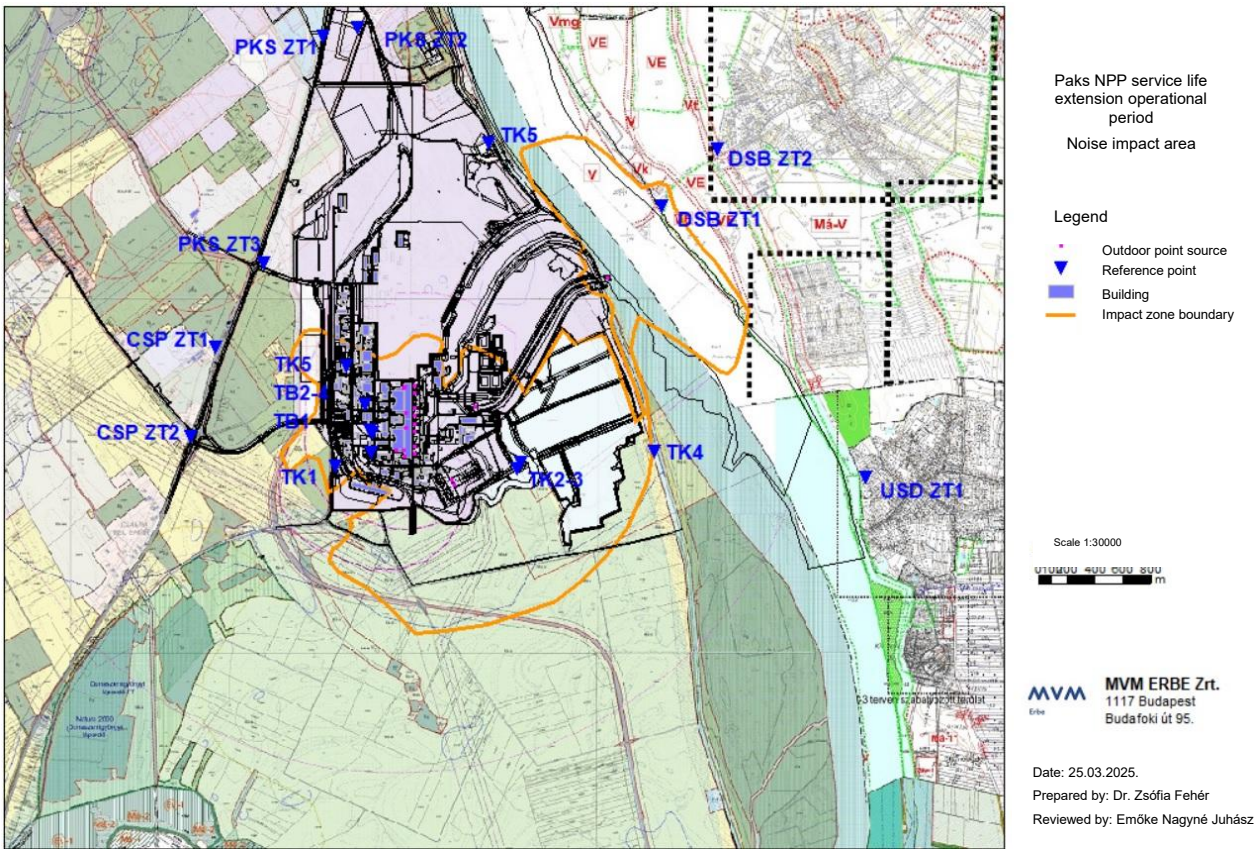
Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.2-1. Noise map for the operational period of the Paks NPP

Based on the comparison with historical data (the EIAR for the first service life extension of the Paks NPP /2006/ and the EIAR for the construction of Paks II NPP /2012/), the noise emission of the power plant has not increased since 2006. Considering the period elapsed since the 2006 assessment for the first service life extension, upgrades have been implemented for emergency equipment. However, the noise sources operating during emergency events in the daytime do not affect the noise impact area.

Compared to the 2012 data (Paks II NPP EIAR), the operational noise exposure of the NPP has not increased over the subsequent 12 years. Based on a detailed noise propagation model derived from on-site noise measurement results from 2024, the current impact area of the Paks NPP from an operational noise protection perspective extends to the administrative boundaries of Paks and Dunaszentbenedek. However, it does not affect residential areas or protected zones located in the vicinity of the power plant.

The noise emissions from the NPP will not have any transboundary impacts, as the impact area is limited to a radius of a few kilometres around the plant. In terms of environmental impact assessment, the operational noise exposure of the NPP can be classified as long-term and neutral with respect to surrounding buildings and areas requiring protection, while it is considered burdensome within the operational site. The noise impact area of the NPP is illustrated in *Figure 4.9.2-2*.



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.2-2. Noise impact area of the Paks NPP from an operational noise protection perspective, displaying the objects to be protected against noise

According to the results of historical assessments, vibration exposure – neither baseline levels nor in respect of the Paks NPP – is unlikely to reach a critical extent.

The indirect impact of the power plant's operation is characterized by the noise emissions of traffic noise sources causing noise exposure, acting as impact factors. The volume of passenger car traffic linked to the operation of the Paks NPP – taking into account the occupancy of external

parking lots, the daily turnover of parked vehicles at individual parking spaces, and the vehicles entering the power plant – is approximately 1,920 cars during the daytime period (between 6:00 and 22:00) and approximately 220 vehicles during the night-time period (between 22:00 and 6:00). The volume of heavy goods vehicles (typically light commercial vehicles) amounts to approximately 450 vehicles during the day and approximately 40 vehicles at night. Motorcycle traffic linked to the Paks NPP is roughly 90 vehicles during the day, and negligible at night. The number of scheduled contracted bus services affecting the power plant on individual road sections is determined by the bus timetable. Vehicles travel in northern and southern directions on Main Road No. 6 and the M6 motorway, operating round trips on these road sections. On the two investigated roads, approximately two-thirds of the vehicles travel northbound and one-third southbound during the day, while their numbers are no longer significant on the sections above the Paks junction (Kölesdi Road). Approximately 10% of the vehicle traffic linked to the power plant continues onto the M6 motorway, while 90% remains on Main Road No. 6. Contracted buses typically do not use the M6 motorway.

Based on the vehicle traffic data linked to the operation of the Paks NPP, higher load values occur on Main Road No. 6 between Dunaszentgyörgy and Paks-North, while no noise exposure increment can be detected on the M6 motorway in relation to operation-related traffic. An indirect impact area develops along the affected road sections of Main Road No. 6, at the residential buildings next to Paks Csámpa Road (*Figure 4.9.2-3.*). In terms of environmental impact assessment, the plant's traffic noise exposure is classified as long-term and falls into the neutral-tolerable categories regarding the protected buildings and protected areas. In 2006, a lower value was calculated for power plant-related traffic, but traffic habits have changed since then, with both general road traffic and power plant-related traffic increasing, and accordingly, proportionally.

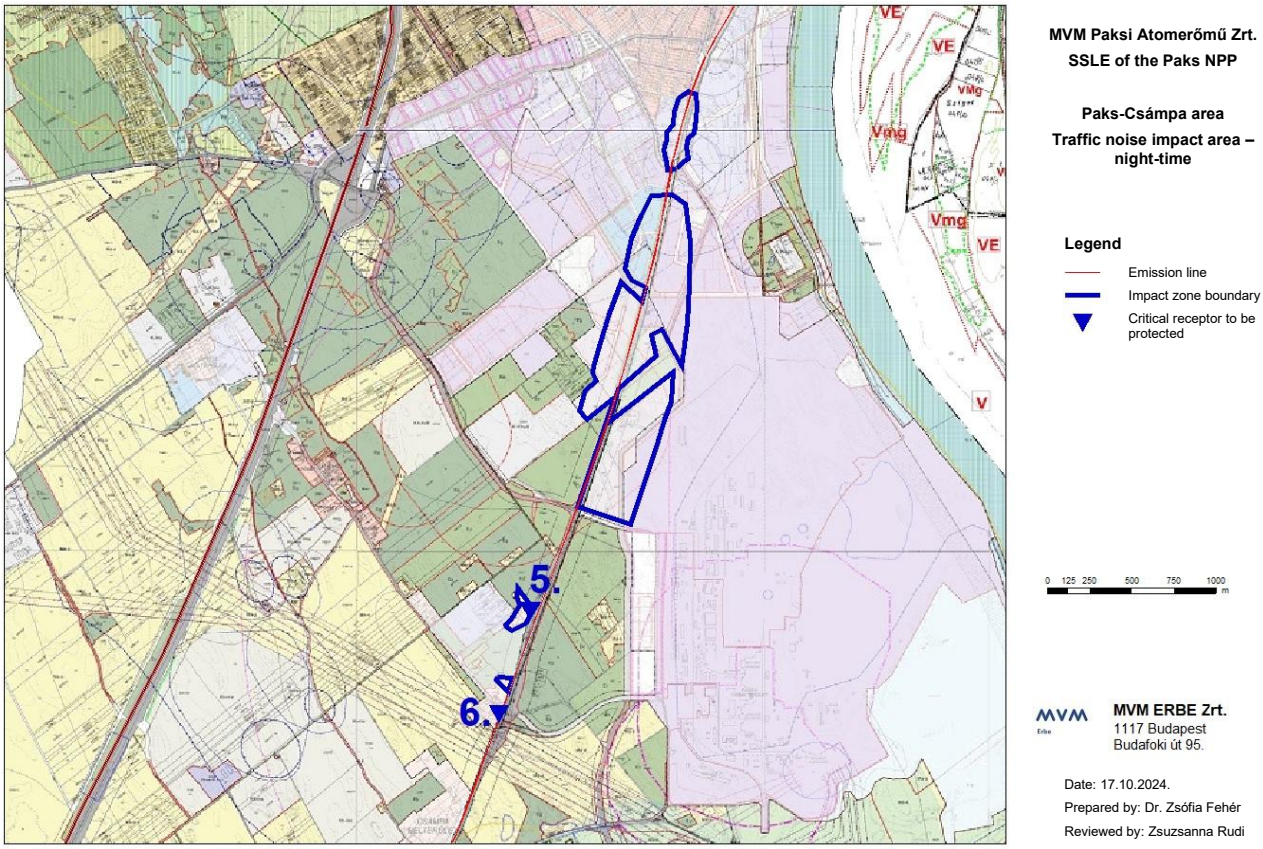


Figure 4.9.2-3. Traffic noise impact area associated with the Paks NPP

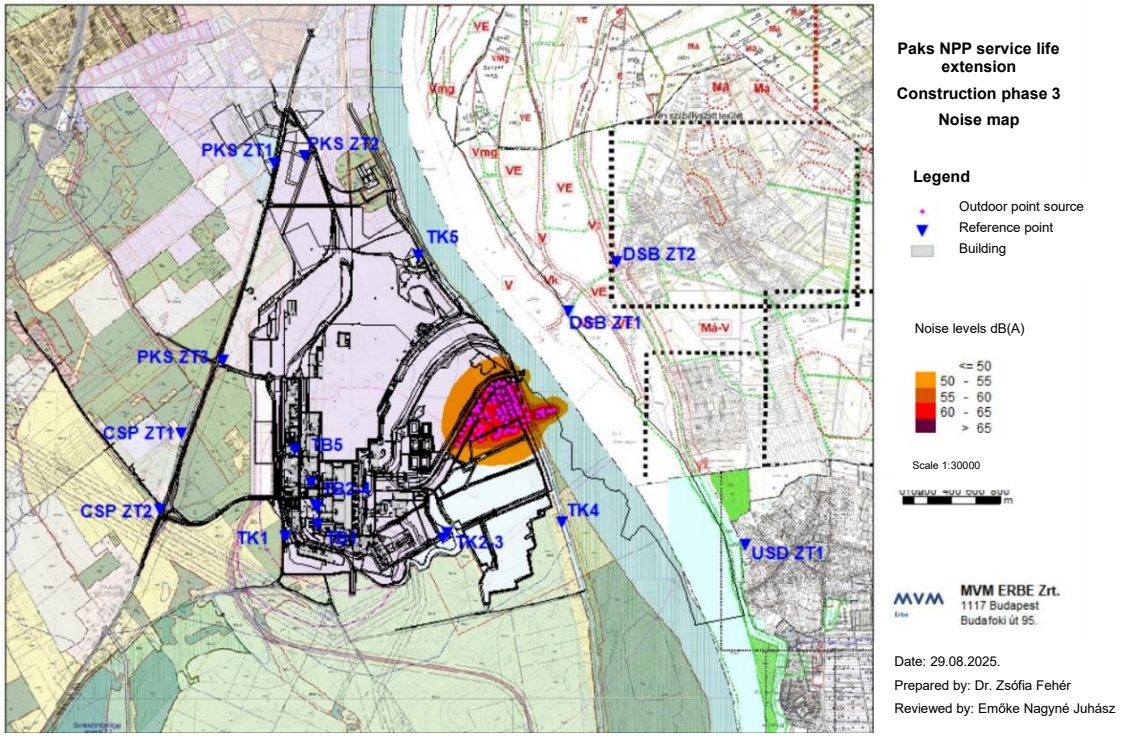
4.9.3. Expected impacts of preparations for the SSLE

Among the activities planned as part of the preparation for the SSLE, significant noise emission is expected to arise from the construction of the alternative warm-water channel section and the peak cooling system. During the construction phase, the impact factors are the construction machinery causing the noise exposure. The stage of the construction phase expected to generate the highest noise exposure is the mechanical earthworks, during which excavators, bulldozers, rollers, scrapers, graders, and heavy goods vehicles are typically operated. Daytime working hours were taken into account for the construction works. The noise exposure from the construction activities during the construction phase involving the highest noise emission and generating the maximum noise load, as well as the noise exposure limit values, are shown in *Table 4.9.3-1*.

Table 4.9.3-1. Noise exposure from construction activities during the construction phase involving the highest noise emission and generating the maximum noise load, alongside the noise exposure limit values

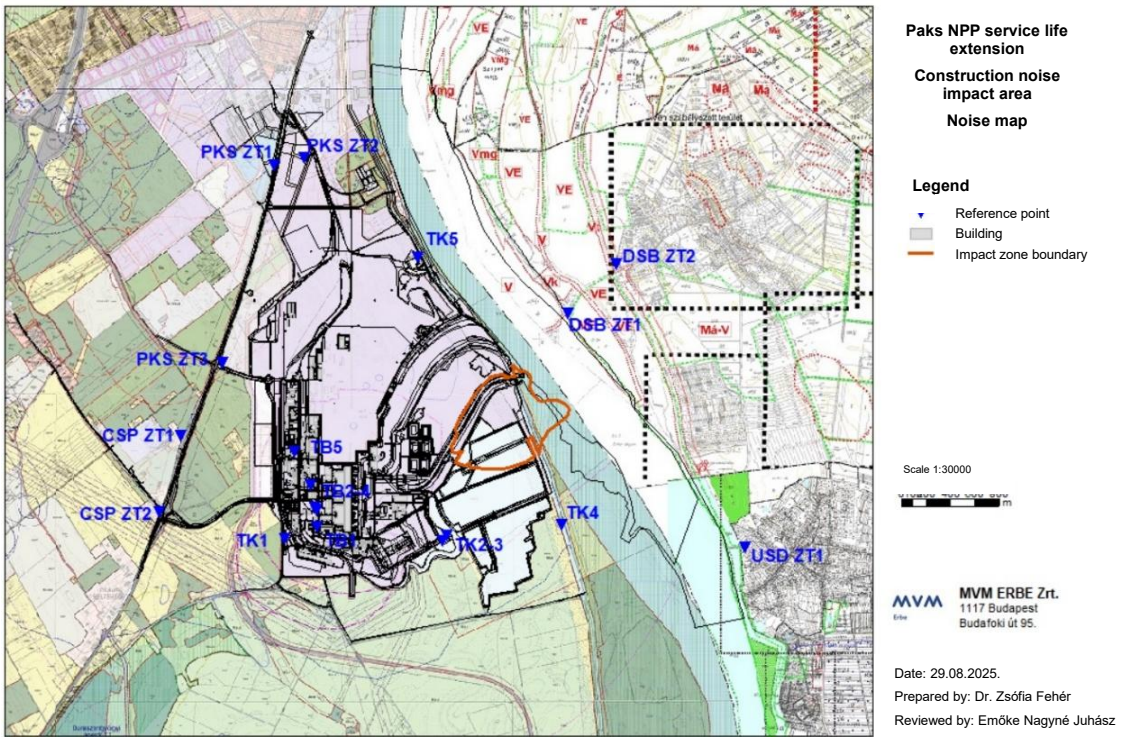
Key	Noise-sensitive receptor, noise-sensitive area	Daytime noise exposure [dB]	Daytime limit value [dB]
PKS ZT1	Worker's hostel under construction in the Vi-M/10 mixed institutional zone, Paks	29	60
PKS ZT2	Area designated for a special medical centre, Paks, plot number: 8802/34	30	50
PKS ZT3	Residential Building at the North Entrance of Paks NPP, Paks, plot number: 057/11	32	65
CSP ZT1	Csámpai Fenyvestanya, 22 Csámpapuszta, Paks, plot number: 0292/2	30	55
CSP ZT2	Csámpai Village Hall, 33 Csámpapuszta (2), Paks, plot number: 0191/23	28	55
DSG ZT1	Residential Building, 22 Béke Square, Dunaszentgyörgy, plot number: 112/1	0	55
DSB ZT2	Residential Building, 3 Zöldfa Street, Dunaszentbenedek, plot number: 581/2	29	55
USD ZT1	Residential Building, 15 Béke Street, Uszód, plot number: 044	31	55
TB4	Medical Clinic, Paks NPP, Paks	34	65
TB5	Fire Station, Paks NPP, Paks	37	65

During the construction of the alternative warm-water channel and the peak cooling system, the noise exposure limit values for construction activities are expected to be met (*Figure 4.9.3-1.*). The noise impact area from a noise protection perspective for the construction of the peak cooling system extends over non-protected zones and the economic area of the Paks NPP, which contains no protected facilities (*Figure 4.9.3-2.*). The impacts resulting from noise emission can be considered neutral for the construction period.



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.3-1. Noise map for the construction phase of the alternative warm-water channel section and peak cooling system involving the highest noise emission



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.3-2. Noise impact area from noise protection perspective for the construction phase of the alternative warm-water channel section and peak cooling system involving the highest noise emission

4.9.4. Changes expected as a result of the SSLE

Regarding the duration of the SSLE, no significant change is expected compared to the current noise exposure, with the exception of the operation of the peak cooling system required during critical periods. Without the operation of the peak cooling system, the current noise load can be expected to continue in the future. Following the commissioning of the peak cooling system, the condition generating the highest noise exposure will be when the warmed cooling water is discharged back into the Danube after passing through the new, alternative warm-water channel and the operating peak cooling system.

During the SSLE period, in addition to the current noise sources of the Paks NPP, additional noise sources will be represented by the new water level control weir, the new energy dissipator structure, the cooling cell fans, the air intakes, the transformer, and the pumps of the pumping station.

During the operation of the Paks NPP with the peak cooling system, the operational noise sources of the system may cause exceedances of the noise exposure limit values. Therefore, the noise mitigation measures for the peak cooling system are designed ensuring that the zoning limit values are met even during the joint operation of the Paks NPP and Paks II NPP.

When the Paks NPP operates with the peak cooling system, the independent noise exposure from the facility is expected to be classified – in terms of EIA regarding the surrounding protected buildings and protected areas – as long-term, burdensome in Uszód, burdensome within the operational site, and neutral in other protected zones.

During the operation of the Paks NPP with the peak cooling system, Paks II NPP will also be operational; accordingly, the cumulative noise exposure and impact area were investigated and presented. In the assessment of the noise exposure during joint operation, the noise sources of the Paks NPP, supplemented by the peak cooling system, and the operational noise sources of Paks II NPP were taken into account. The latter include technological equipment located in the open areas of Paks II NPP or linked to its buildings that interact with the atmospheric environment.

The noise exposure associated with the joint operation of the Paks NPP and Paks II NPP is expected to approach the zoning limit values at the nearest residential zones, both with and without taking into account the operation of the Paks NPP's peak cooling system. However, with appropriate noise mitigation measures, it will not exceed them.

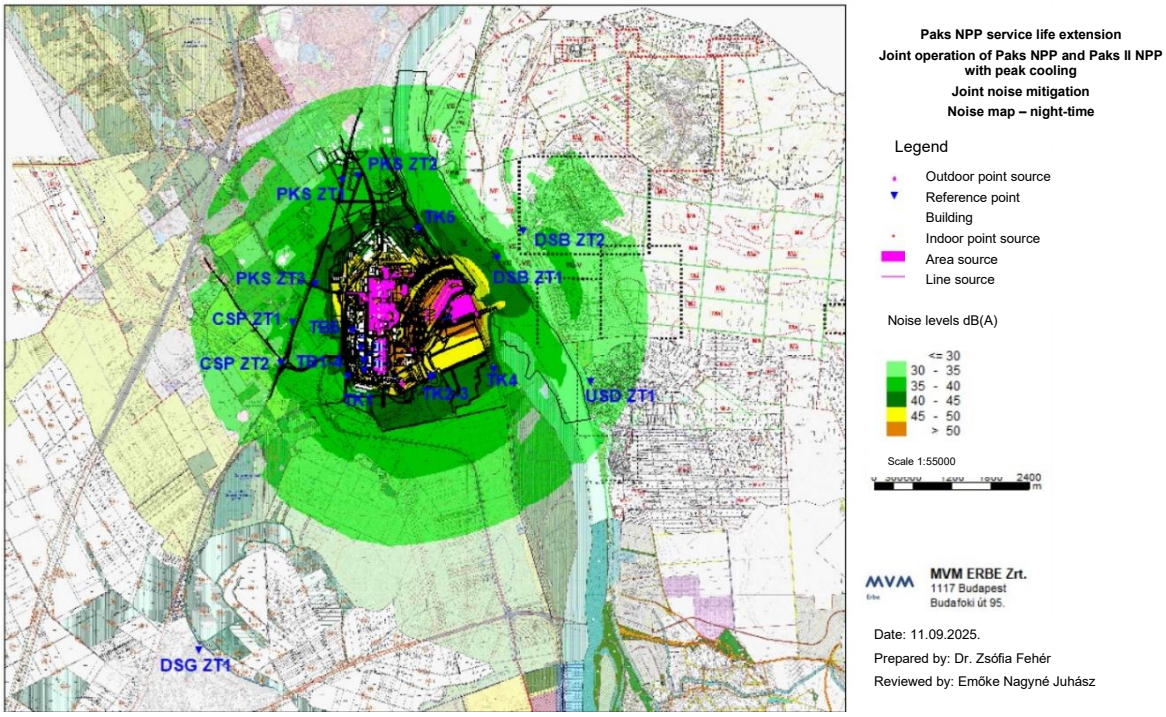
During the deployment of the Paks NPP’s peak cooling system, noise mitigation measures must be designed in a way that the noise exposure levels – which are already expected to be close to the noise limit values – do not increase, and the impact area does not expand significantly. It may be necessary to install a noise barrier wall along the southern and eastern boundaries of the medical center. A decision on this matter will need to be made based on post-implementation verification measurements and the actual baseline exposure.

The calculated noise exposure values resulting from the joint operation of the Paks NPP operating with the planned peak cooling system and Paks II NPP are shown in *Table 4.9.4-1*. The cumulative noise emission from the joint operation of the Paks NPP with the peak cooling system and Paks II NPP is illustrated by the noise map shown in *Figure 4.9.4-1*.

The noise impact area from a noise protection perspective for the joint operation of the Paks NPP and Paks II NPP – both with and without taking into account the Paks NPP’s peak cooling system – extends over the administrative territories of Paks, Dunaszentbenedek, and Uszód, also affecting the surrounding residential zones of Paks-Csámpa, Dunaszentbenedek, and Uszód (*Figure 4.9.4-2.*).

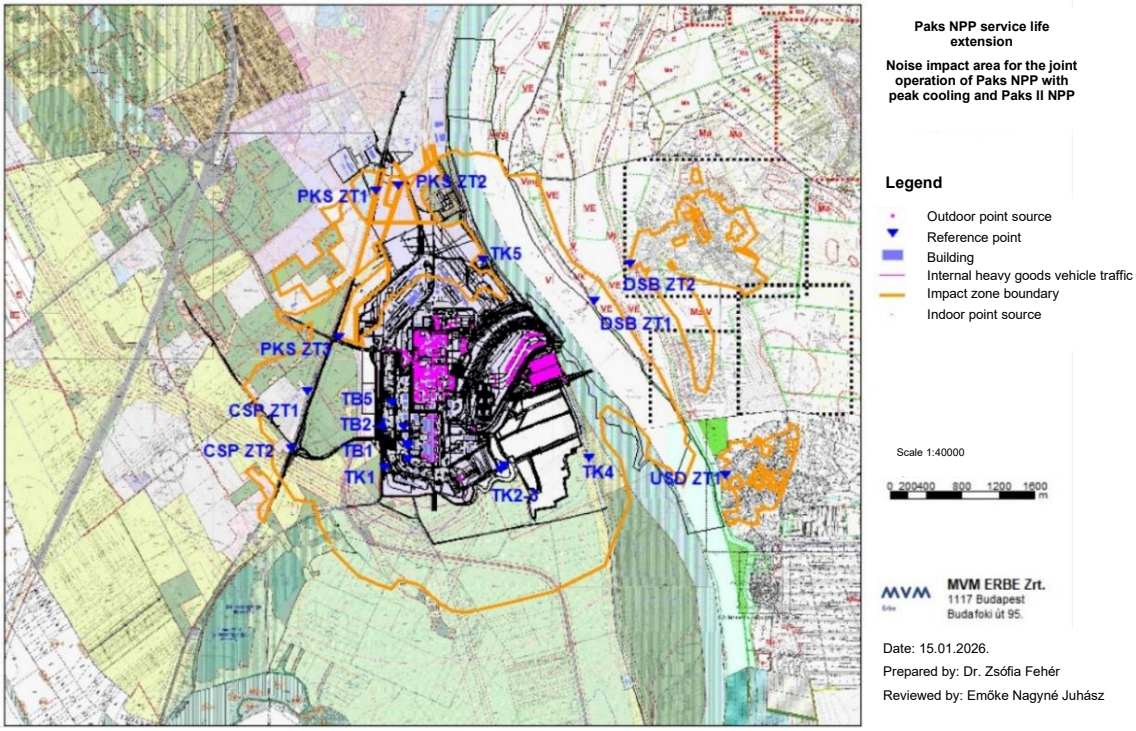
Table 4.9.4-1. Operational noise exposure resulting from the joint operation of Paks II NPP and the Paks NPP operating with the peak cooling system

Key	Noise-sensitive receptor, noise-sensitive area	Limit value Daytime / Night-time [dB]	Noise exposure with noise mitigation Daytime/Night-time [dB]
PKS ZT1	Worker's Hostel under Construction in the Vi-M/10 Mixed Institutional Zone, Paks	55/45	36/36
PKS ZT2	Area designated for a special medical center, Paks, plot number: 8802/34	45/35	36/36
PKS ZT3	Residential Building at the North Entrance of Paks NPP, Paks, plot number: 057/11	60/50	42/42
CSP ZT1	Csámpai Fenyvestanya, 22 Csámpapuszta, Paks, plot number: 0292/2	50/40	40/40
CSP ZT2	Csámpai Village Hall, 33 Csámpapuszta (2), Paks, plot number: 0191/23	50/40	36/36
DSG ZT1	Residential Building, 22 Béke Square, Dunaszentgyörgy, plot number: 112/1	50/40	5/5
DSB ZT2	Residential Building, 3 Zöldfa Street, Dunaszentbenedek, plot number: 581/2	50/40	34/34
USD ZT1	Residential Building, 15 Béke Street, Uszód, plot number: 044	50/40	33/33
TB4	Medical Clinic, Paks NPP, Paks	60/50	46/46
TB5	Fire Station, Paks NPP, Paks	60/50	49/49



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.4-1. Noise map for the joint operational period of Paks II NPP and the Paks NPP operating with the peak cooling system



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.4-2. Noise impact area from noise protection perspective for the joint operation of Paks II NPP and the Paks NPP operating with the peak cooling system

Based on the baseline historical vibration measurements – investigated within the framework of the impact assessment of the Paks II NPP – the environmental vibration exposure of the Paks NPP is below the limit values. The vibration exposure arising from traffic associated with the operation of the power plant is expected to be non-significant. No impact area can be defined for vibration exposure. In terms of EIA, the vibration exposure during the joint operation of the Paks NPP and Paks II NPP is expected to be a long-term impact on receptors. However, it can be classified into the neutral category. Regarding vibration sources, no changes are anticipated for the duration of the SSLE, and the current load can be taken into account during the period of the SSLE.

There will be no transboundary impact, as the impact area is limited to a radius of a few kilometres around the NPP.

Determining the future share of traffic noise exposure associated with the operation of the Paks NPP is subject to significant uncertainties. Assuming the worst-case scenario (the maximum impact area), an impact area caused by exposure values that exceed 3 dB by a few tenths of a decibel – representing the current conditions – can be assumed at the beginning of the initial years of the SSLE. Examining the longer-term forecast (15 years, or the full operational period of the power plant until 2057), it is more likely that in the distant future, no impact area will develop along the affected roads as an indirect impact of the NPP. This is because the baseline traffic of the roads increases relatively each year, compared to which the noise impact area resulting from the traffic noise exposure of the Paks NPP will relatively decrease or become undetectable. The Paks-Kalocsa Danube Bridge (Tomori Pál Bridge) does not significantly affect the traffic noise exposure of the power plant. During the operational phase of the SSLE period, indirect impacts can be considered neutral.

Based on the data from the Paks II NPP EIAR prepared in 2012, the traffic noise impact of Paks II NPP could be estimated. The road traffic noise exposure of Paks II NPP causes a small noise exposure increment along Main Road No. 6, slightly expanding the indirect impact area of the Paks NPP. The cumulative indirect impact area of the Paks NPP and Paks II NPP potentially develops at the residential buildings next to Paks-Csámpa and the Dunaszentgyörgy road during

the initial years of the SSLE (*Figures 4.9.4-3. and 4.9.4-4.*). The cumulative traffic noise exposure of the Paks NPP and Paks II NPP is classified as long-term in terms of the EIA, and regarding protected buildings and protected areas, it is expected to fall into the neutral-tolerable categories depending on the location. In the distant future, no impact area will develop as an indirect impact along the affected roads due to the cumulative traffic noise exposure of the Paks NPP and Paks II NPP.

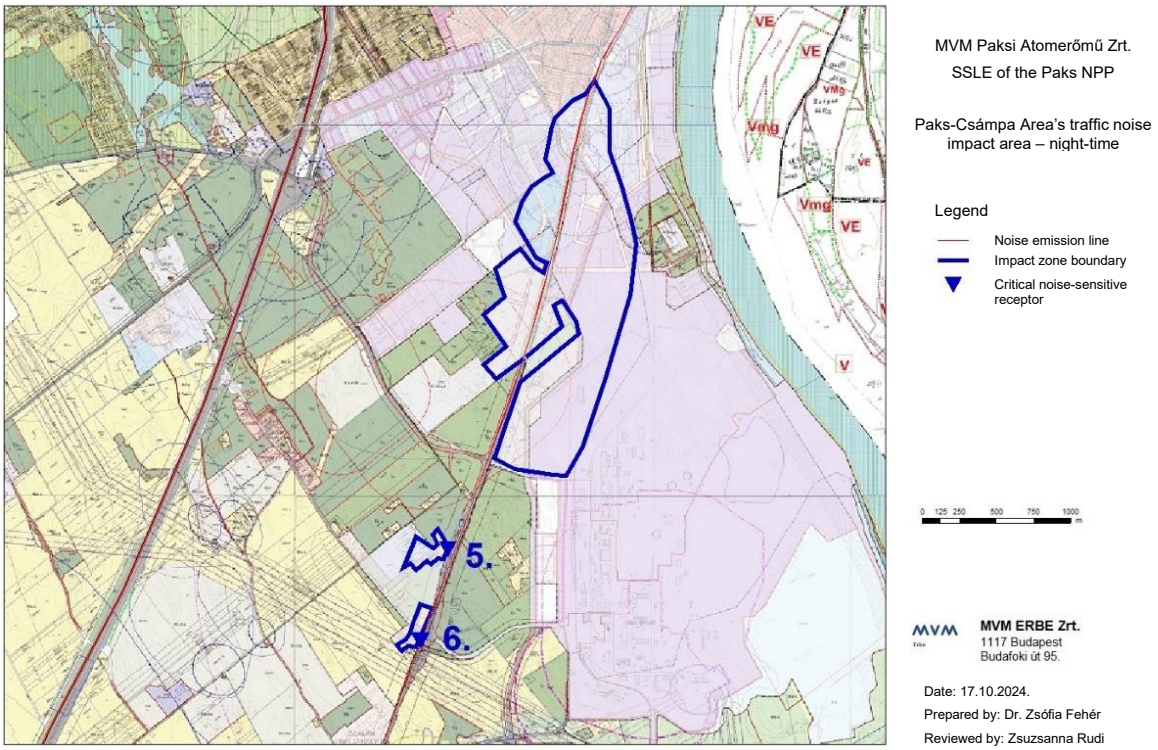


Figure 4.9.4-3. Noise impact area of traffic associated with the joint operation of Paks NPP and Paks II NPP (initial years of SSLE) – Paks-Csámpa (Main Road No. 6)

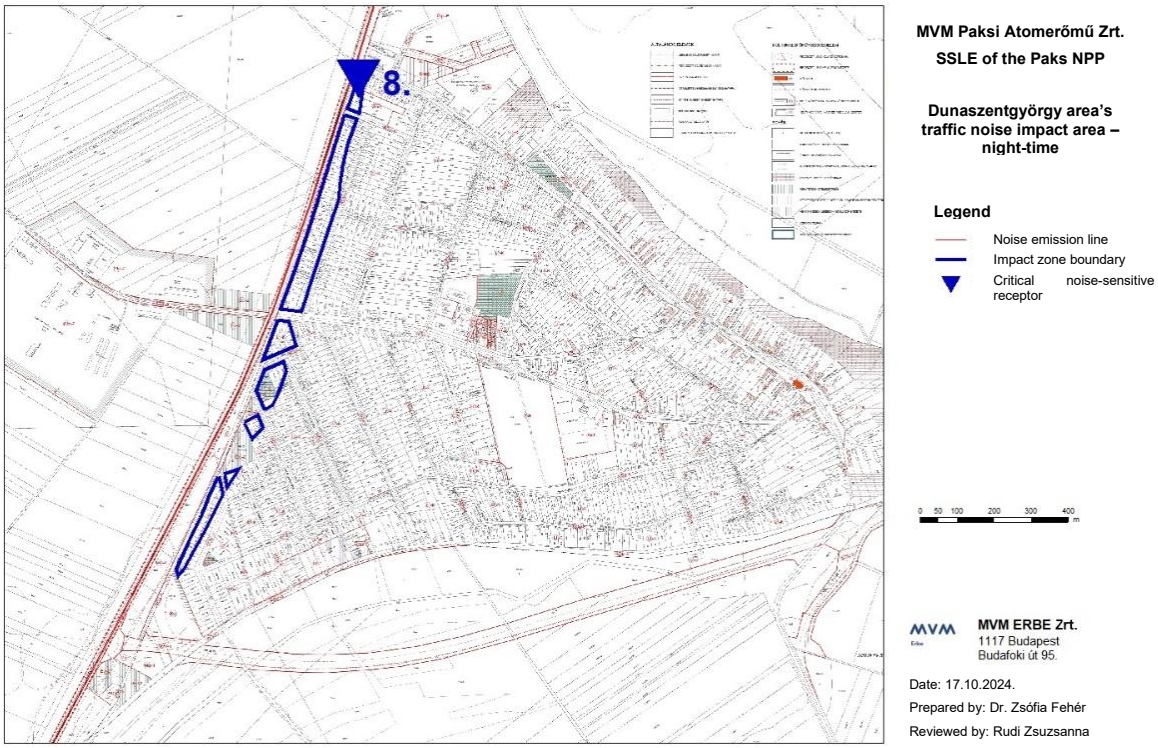


Figure 4.9.4-4. Noise impact area of traffic associated with the joint operation of Paks NPP and Paks II NPP (initial years of SSLE) – Dunaszentgyörgy (Main Road No. 6)

4.9.5. Impacts of emergency events

From a noise emission perspective, the simultaneous loss of external power supply and internal AC power supply (on all four units) was taken as the baseline emergency event (blackout). The probability of occurrence for such a significant emergency event is very low.

The impact factors during an emergency event are the noise emissions from noise sources that operate in the event of a malfunction, causing noise exposure. For the emergency event condition, the partial operation of main operational buildings I-II was taken into account. Compared to normal operation, the point-source noise emissions from the roof were supplemented by the noise emissions from the atmospheric steam dump valves. Additionally, the noise emissions from the emergency diesel generators must also be factored into the emergency event operational condition.

From a noise exposure perspective, the noise emission during an emergency remains below the noise exposure limit values at the nearest protected buildings and protected areas, provided that the emergency event occurs during the daytime (*Table 4.9.5-1.*). The noise exposure exceeds the limit values at the majority of the assessment points if the emergency event occurs at night. There is a significant difference between daytime and night-time noise exposure (*Figures 4.9.5-1. and 4.9.5-2.*) because the noise sources generating the highest noise load operate intermittently, and this noise exposure is averaged over the assessment period, which differs between night and day.

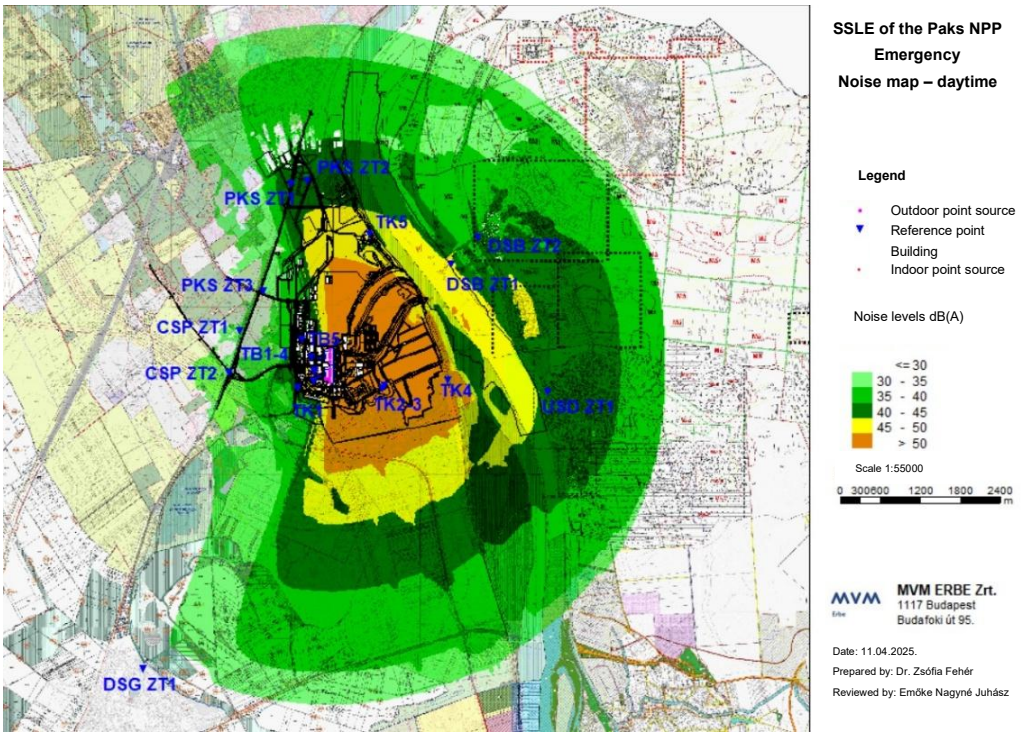
Since the acoustic design is tailored to the most frequently occurring noise exposure, the comparison with the limit values is for informational purposes only.

Table 4.9.5-1. Operational noise exposure of Paks NPP during emergency events and relevant limit values

Key	Noise-sensitive receptor, noise-sensitive area, reference point	Limit value [dB] Daytime / Night-time	Noise exposure [dB] Daytime/ Night-time
PKS ZT1	Workers' hostel under construction in the Vi-M/10 mixed institutional zone in Paks	55/45	42/53
PKS ZT2	Special healthcare center zone in Paks, plot number: 8802/34	45/35	43/54
PKS ZT3	Residential building near the northern entrance of the Paks NPP, plot number: 057/11	60/50	33/43
CSP ZT1	22 Csámpapuszta, Csámpai Fenyvestanya, Paks, plot number: 0292/2	50/40	37/47
CSP ZT2	Csámpai Village Hall, 33 Csámpapuszta (2), Paks, plot number: 0191/23	50/40	32/40
DSG ZT1	Residential Building, 22 Béke Square, Dunaszentgyörgy, plot number: 112/1	50/40	–/–
DSB ZT2	Residential Building, 3 Zöldfa Street, Dunaszentbenedek, plot number: 581/2	50/40	43/54
USD ZT1	Residential Building, 15 Béke Street, Uszód, plot number: 044	50/40	43/54
TB4	Medical Clinic, Paks NPP, Paks	60/50	60/64
TB5	Fire Station, Paks NPP, Paks	60/50	45/54

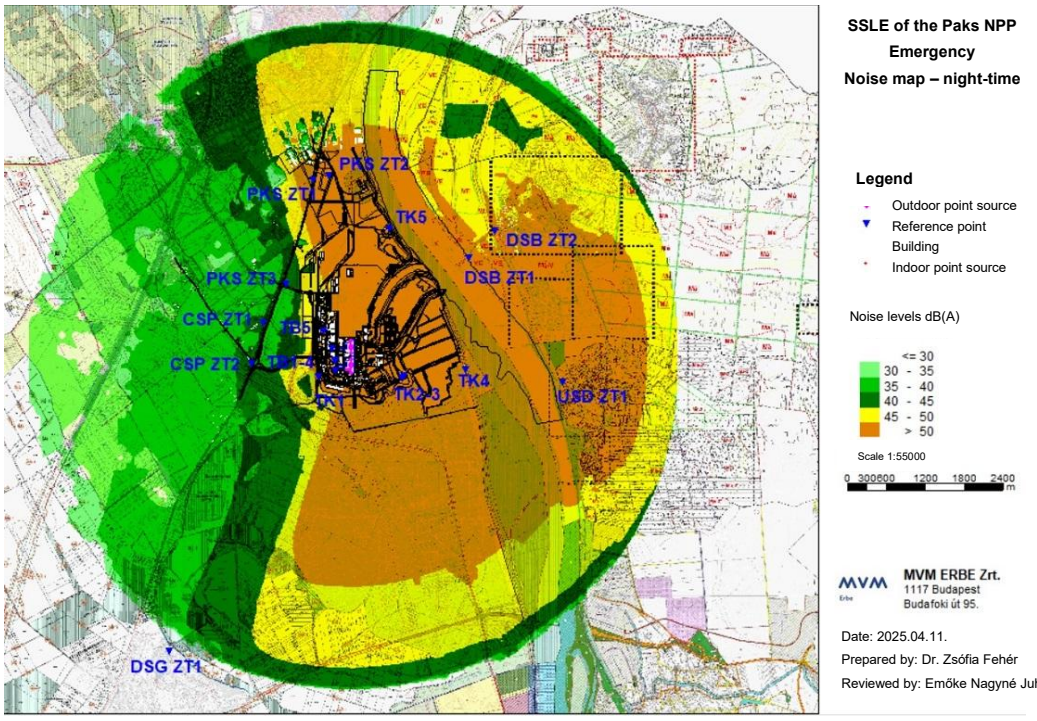
In the event of an emergency, the noise impact area from a noise protection perspective varies in size by direction according to the zoning categories, and the farthest point is expected to be approximately 5.1 km from the center of gravity of the Paks NPP (*Figure 4.9.5-3.*). In terms of EIA, the emergency event operational noise exposure of the NPP is a short-term and heavy impact regarding the surrounding protected building facades and protected areas. The emergency event impact area affects the settlements of Paks, Dunaszentgyörgy, Uszód, Foktő, Dunaszentbenedek, and Géderlak.

Outdoor point source
Reference point
Building
Indoor point source



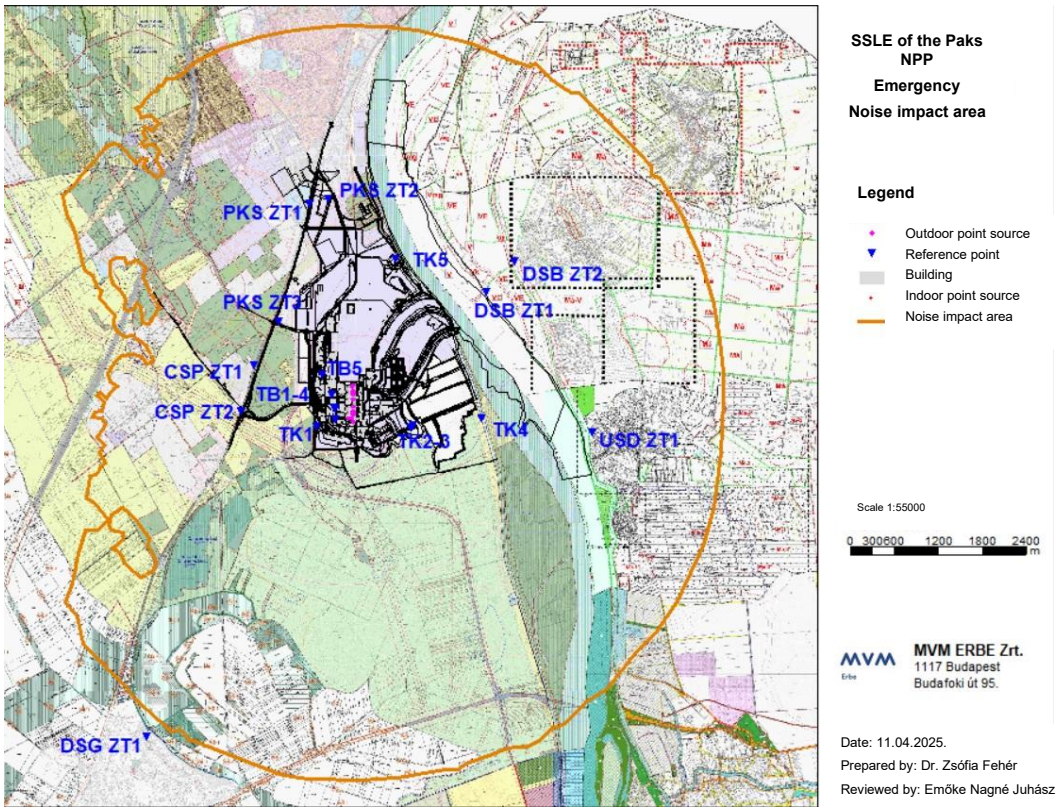
Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.5-1. Noise map for the operational noise exposure of the Paks NPP in the event of emergency – daytime



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.5-2. Noise map for the operational noise exposure of the Paks NPP in the event of emergency – night-time



Legend: PKS: Paks, CSP: Csámpa, DSB: Dunaszentbenedek, USD: Uszód, DSG: Dunaszentgyörgy, ZT: noise receptor point.

Figure 4.9.5-3. Noise impact area of the Paks NPP's operational noise exposure in the event of emergency

4.10. Social and economic impacts

4.10.1. Demographic outlook of the site and its broader environment

The methodology used for the demographic projection of the investigated area combined cohort-component and agent-based modelling methods. This hybrid methodology provided inputs, among others, for the National Adaptation Geo-information System (NAGiS) (Lennert-Farkas 2018, Lennert 2019). The methodology applied for the projection was a refinement of the previous version, using the data from the recent 2022 census as a starting point and taking into account the demographic events that occurred during the period elapsed since the 2011 census. In the model run, the 2022 census served as the starting point, and the cohorts contained 5-year age groups by gender at the settlement level. Each cycle consisted of 5 years, thereby modelling the temporal evolution of the population in 8 cycles up to 2062. The model run was executed using a script written in Python, prepared by the HUN-REN Research Centre for Astronomy and Earth Sciences.

The future evolution of the population was examined along 6 scenarios and 2 dimensions (demographic and Paks-specific). The scenario variants of the demographic dimension (high, baseline, low) differ in their fertility, mortality, and migration assumptions. The high scenario assumes faster-growing life expectancy, increasing fertility, a positive international net migration, and a reduction in domestic demographic disparities, whereas the low scenario assumes a slower increase in life expectancy, lower fertility, a negative international net migration, and an intensification of domestic demographic disparities. The baseline scenario represents a middle ground, assuming the persistence of currently observed regional disparities. The Paks-specific dimension factored in the SSLE (through the sustained joint operation of the Paks NPP and Paks II NPP), as well as its absence. In the case of the former, the labour demand of the Paks II NPP emerges as an additional requirement, which could result in the arrival of nearly

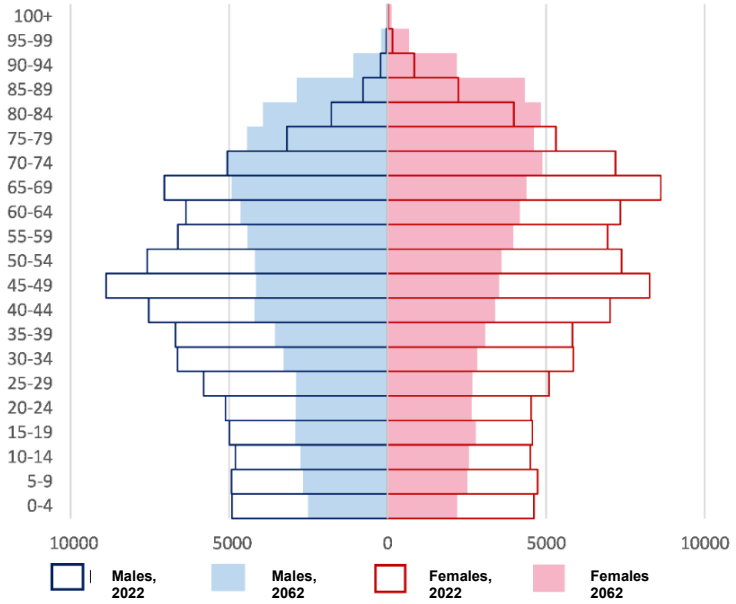
1,500 people in total to the region. In the case of scenario variants assuming the absence of the SSLE, the arrival of additional workers into the investigated area is unlikely for the modelled period. In this case, upon the commissioning of Paks II NPP, its labour demand will be met either through the transition of employees, or through the replacement of employees within the region. A limitation of the applied methodology for scenarios assuming the absence of commissioning is that they rely purely on different demographic assumptions (the presented low, baseline, and high scenario variants). When presenting the results of the population projection, each scenario is outlined. However, the scenario deemed most probable, which includes the baseline demographic assumptions and assumes the SSLE of the Paks NPP, is highlighted (Paks-baseline scenario).

In the modelled period between 2022 and 2062, a significant decline in Hungary's population is expected, which will also apply to the 75 settlements in the investigated area. The results of the developed scenarios do not differ in their fundamental trends, only in the extent of the population decline. Under the high scenario, the national population loss could be 11%, whereas a 24% loss is expected for the investigated area by 2062. Under the baseline scenario, the national population in 2062 would be 78% of the 2022 population, while in the investigated area, this figure is only 65%. The national population loss of 32% in the low scenario is also significantly outperformed by the 45% loss in the investigated area. Ultimately, the demographic outlook for the investigated area is substantially worse than the national average; during the modelled period, even under the baseline scenario deemed most probable, it could lose a third, or even close to half, of its population.

Scenarios assuming the SSLE present a slightly more favourable outlook, with low, baseline, and high projections forecasting a higher population figure (low: 115,000 people; baseline: 134,000 people; high: 156,000 people). Although the impact of the SSLE is favourable, it cannot significantly influence the demographic processes of the investigated area. With the commissioning of Paks II NPP, the workers and their family members expected to arrive in the Paks region, as well as the resulting spillover demographic effects (e.g., children born to the relocating population), can only mitigate the population decline compared to 2022 by a mere 1-2 percentage points. The rapid population loss of the site and its broader environment is primarily driven by unfavourable natural demographic dynamics. As a summation of the expected demographic processes, there are settlements within the investigated area where the population change outlooks for the modelled period are much more unfavourable, but also some where they are much more favourable compared to the Paks region as a whole. Differing natural demographic scenarios primarily influence the extent of population loss, while the realization of service life extension, involving 1,500 additional people in the modelling, is expected to result in their settlement in Paks. Consequently, while the positive demographic impact of the service life extension is anticipated to be modest across the Paks region as a whole, its implications at the individual settlement level could be substantial. Indeed, the various demographic scenarios uniformly project a population expansion specifically for the town of Paks. Although the future capacity of Paks to attract labour will likely fall short of the assumptions utilized in the projection, its overall demographic outlook – in alignment with the model simulation outputs – is still projected to be substantially stronger than that of the surrounding region.

According to the projections, the significant changes will affect not only the population size but also its age structure. While the proportion of the young and active age groups will shrink by half by 2062, a substantial increase in the proportion of the oldest age groups is expected in the long term, thanks to the increasing life expectancy (*Figure 4.10.1-1.*). All this may be accompanied by a significant shift in the old-age dependency ratio. While data from the 2022 census showed that there were 36 elderly people per 100 working-age people in the investigated area, this value could increase to 57 by 2062 based on the results of the Paks-Baseline scenario. Even more profound spatial disparities are anticipated regarding the restructuring of the age composition *(Figure 4.10.1-2.*). While the 2022 census data reveal no clear spatial pattern across the Paks region and the baseline variations remain narrow, the disparities in municipal aging trends are projected to widen substantially by 2062. Paks and Szekszárd are projected to maintain the most optimal age structures. This is due to their status as prime destination hub for workers, enabling

them to effectively retain their working-age resident base and continuously attract a younger demographic.



Source: Own calculation based on HCSO Census 2022 data.

Figure 4.10.1-1. Population pyramid of the assessment area based on the 2022 Census and the projected population for 2062 according to the Paks-baseline scenario

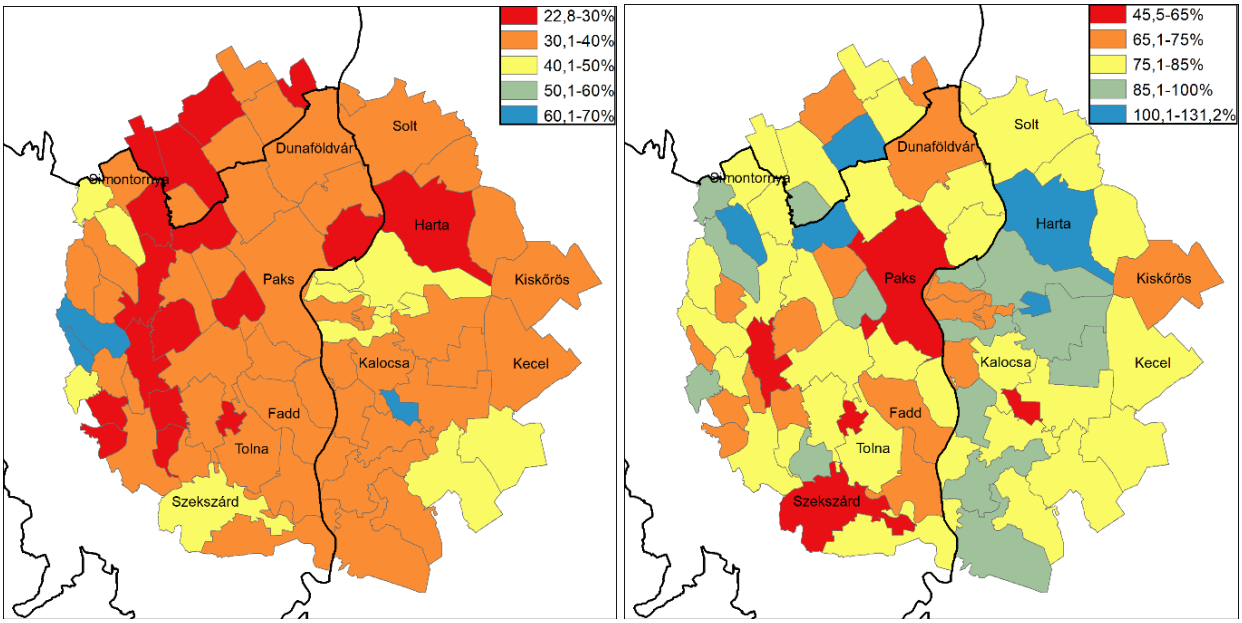


Figure 4.10.1-2. Old-age dependency ratio in 2022 (left) and 2062 (right) based on the results of the Paks-baseline scenario

In conclusion, future population dynamics across the site and its broader surroundings will remain characterized by steady population contraction. This trajectory will fundamentally reshape the population's age structure, driving a pronounced shift toward demographic aging. Within the investigated area, these projected demographic trends will be shaped by profound spatial disparities, with a significantly stronger outlook projected primarily for Szekszárd and Paks up to 2062. This advantage will manifest in a more moderate population decline, an enhanced capacity to attract workforce, a younger demographic profile, and a larger employment base.

4.10.2. Economic situation of the site and its broader environment and its expected evolution

The descriptive statistical analysis of economic characteristics relied on data from the HCSO[11], the HCSO Censuses[12] and the National Spatial Development and Spatial Planning Information System[13] (TeIR). For methodological reasons, data processing covered not only the investigated area – namely the Paks region and the 75 municipalities examined within it – but also the three affected counties (Tolna, Fejér, Bács-Kiskun) primarily as a basis for comparison. While the statistical data analysis is suitable for assessing the economic situation of the investigated area within the country, a methodological limitation is that it is only partially adequate for identifying differences between individual municipalities. This was primarily addressed by forming assessment groups from the examined settlements based on their geographical location within the respective counties.

The economic strength of the site's broader environment is relatively weak on a national scale (*Figure 4.10.2-1.*). On a national scale, Tolna County constitutes the second smallest regional economy in Hungary, ahead only of Nógrád County. Its contribution to the national GDP has averaged just 1.7% since 2010, reflecting a stagnant and marginally downward trajectory. In contrast, Bács-Kiskun County shows a much stronger performance, generating an average of 3.9% of Hungary's GDP; this share began to grow after 2010 but has been in decline since reaching its peak of 4.2% in 2018. Fejér County is the region with the fourth largest economic performance in the country, accounting for 4.2% of the national output. The level of development measured in GDP per capita for Tolna and Bács-Kiskun counties is roughly similar, standing between approximately 70% and 80% of the national average. While Tolna County's economic development in this respect has stagnated since 2010, showing a minor downward trend, Bács-Kiskun County experienced substantial relative growth up to 2020 (climbing from 67% to 81%). This expansion was driven by large-scale projects, such as the Mercedes-Benz greenfield investment in Kecskemét, though it has seen a slight contraction since then, settling at 76% in 2022. Fejér County ranks among the most economically advanced regions in Hungary. Following the downturn induced by the financial and economic crisis, its national standing has seen almost uninterrupted growth, with its per capita GDP consistently outpacing the nationwide average since 2015 by roughly 3% to 6%. In terms of purchasing power parity and measured in euros, Hungary's GDP per capita relative to the EU27 average increased from 40% to 49% between 2010 and 2022, while the same index improved from 30% to 37% in Tolna County and rose from 27% to 37% in Bács-Kiskun County over the same period (albeit not continuously, as it had reached a higher level of 39% in 2019). The relative economic development of Fejér County measured in euros rose from 35% to 51%[14].

The share of different economic sectors in the gross value added varied significantly in 2022 across the affected counties. Tolna County's manufacturing industry accounted for only 18% of the total gross value added, while this proportion stood at 27% in Bács-Kiskun County and 32% in Fejér County. Due to the specific characteristics of Tolna County, a relatively high proportion (12%) of the gross value added was generated by industrial activities including the electricity generation sector (mining and quarrying + electricity, gas, steam, and air conditioning supply + water supply, sewerage, waste management, and remediation activities); the national average for this sector was 2.4%, while it stood at 1.7% in Bács-Kiskun County and 0.8% in Fejér County. In all three counties, the weight of the construction industry was also stronger compared to the national average: standing between 7% and 10% against the 6% national economic average. In the economies of Tolna and Bács-Kiskun counties – compared to the national average of 3.8% – the share of the agricultural sector within the total gross value added was 8-9%, while in Fejér County, this figure was 4.5%. The economic sectors of public administration, education, and human health and social work activities are overrepresented in the examined counties compared

[11] https://www.ksh.hu/

[12] https://nepszamlalas2022.ksh.hu

[13] https://www.oeny.hu/oeny/teir/#/

[14] Source of data: Eurostat (https://ec.europa.eu/eurostat).

to the national average. However, higher value-added services have a lower relative weight compared to the national levels (except for the wholesale and retail trade, transport, and accommodation and food service activities sectors in Bács-Kiskun County).

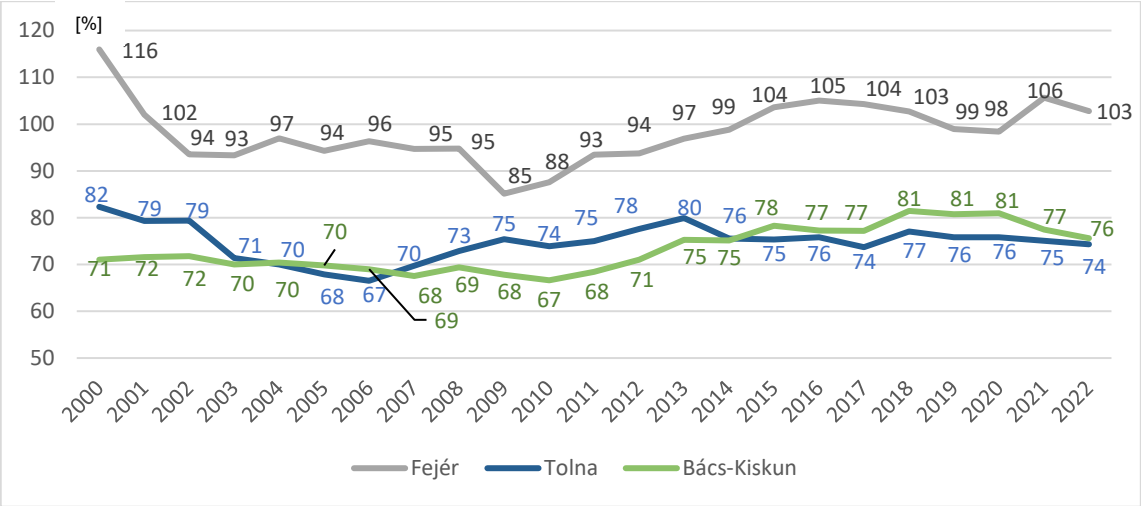


Figure 4.10.2-1. GDP per capita in the three affected counties as a percentage of the national average (2000-2022)

In 2022, 3.6% of the country's local business tax (HIPA) revenues was generated in Bács-Kiskun County, compared to 1.6% in Tolna County and 4.5% in Fejér County. The 75 examined municipalities collectively accounted for an annual average of 1.6% to 1.9% of the national local business tax revenues between 2014 and 2022. Among the examined municipalities, 27 belong to Bács-Kiskun County, accounting for 10-12% of the total county local business tax (HIPA) revenues. Forty municipalities belong to Tolna County, with 74-78% of the total county HIPA revenues linked to them. The town of Paks alone generated 34-43% of the county HIPA revenues between 2014 and 2022. The town of Paks also accounted for a 0.6-0.8% share of the local business tax (HIPA) revenues of the entire national economy. The county seat, Szekszárd, claimed 16-20% of Tolna County's HIPA revenues, while Dunaföldvár's share within the county averaged 9%. The remaining 37 settlements of Tolna County collectively accounted for between 10% and 11% of the county's HIPA share. Among the examined municipalities, only 8 belong to Fejér County, with their share of local business tax (HIPA) revenues within the county hovering around 0.4-0.5%. The average per capita HIPA revenues in the 75 examined settlements were close to the national average (HUF 28.1 thousand), standing at HUF 28.4 thousand between 2018 and 2022. In Paks, the per capita HIPA revenue was nearly ten times the national average (HUF 275.4 thousand) based on the average for 2018-2022. Among the 75 examined municipalities, there was a total of 20 where the per capita HIPA revenue was higher than the national average. However, in 18 municipalities, it was a mere HUF 10 thousand or less.

In February 2024, there were more than 67,000 public workers in Hungary, of whom a total of 965 people were in the examined settlements, representing approximately 1.4% of the national headcount. The public employment indicator – meaning the ratio of the monthly average number of participants in public employment relative to the working-age population – stood at a national average of 1.07%; compared to this, the value of the indicator hovered around 0.8% in the examined towns, whereas it averaged 1.75% in the villages.

In 2022, the number of registered jobseekers in the investigated area was 5,130 people, which was approximately 2% of the national total (236,956 people) (HCSO 2022). In 2022, there was a national average of 4.44 jobseekers per 100 residents of working age (15-64 years), but this value was 3.38 people for the 75 examined settlements. The value of the indicator was 2.4 jobseekers in the county seat (Szekszárd), 2.6 in the towns, 3 in the large villages, and 3.6 in the villages per 100 residents aged 15-64. In the town of Paks, this figure stood at 2.1 in 2022.

The national average of personal income tax (PIT) per capita was HUF 1 million 731 thousand; within the assessment area, it was slightly lower in the examined settlements, standing at HUF 1 million 715 thousand in 2022, though significant differences exist between the individual municipalities (*Figure 4.10.2-2.*). In the county seat, Szekszárd, this value was HUF 2 million 406 thousand, in the towns HUF 1 million 977 thousand, and in the villages only HUF 1 million 650 thousand. The value of the indicator in Paks was HUF 3 million 681 thousand in 2022, which significantly exceeded even the capital city average (HUF 3 million 027 thousand). Among the 75 examined municipalities, the per capita income exceeded HUF 2 million in only 15 settlements, stood between HUF 1.5-2.0 million in 35 settlements, and between HUF 1.0-1.5 million in 21 settlements, while in the two poorest municipalities, Szakadát and Kalaznó, it did not even reach HUF 1 million.

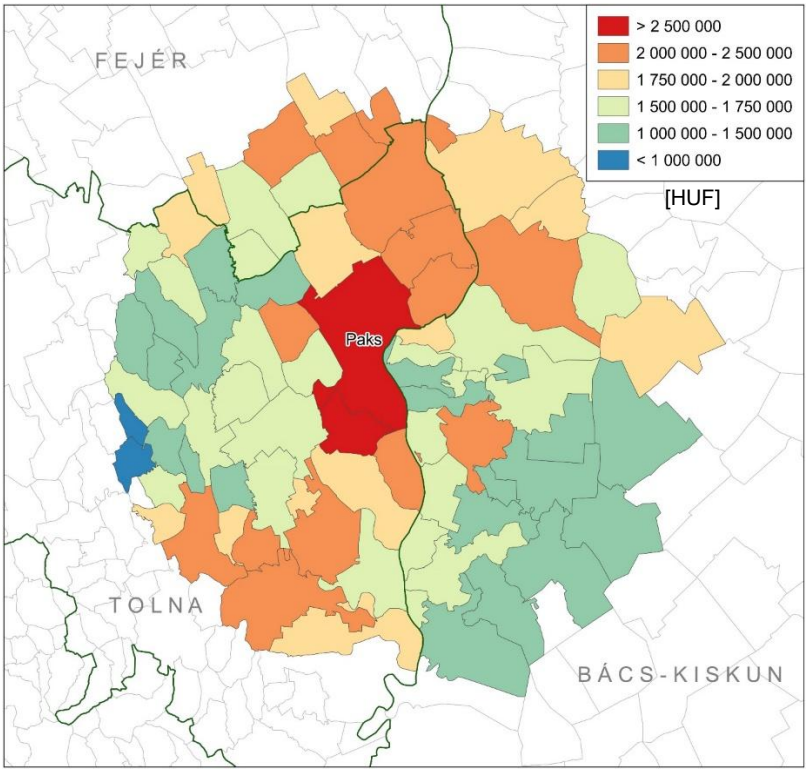


Figure 4.10.2-2. Per capita domestic income forming the personal income tax (PIT) base in the settlements of the investigated area (2022)

In the 75 examined municipalities, 15,585 operating enterprises can be identified, accounting for 1.9% of all enterprises in Hungary (TeIR 2019). Nearly a fifth of these enterprises were located in the county seat, Szekszárd, while almost half of the enterprises were in the other towns. Approximately a third of the enterprises were located in the villages and large villages. On average, there were 213 enterprises per settlement, a figure that is slightly higher in Bács-Kiskun County (228 companies), but stands at a mere 61 registered companies in Fejér County. In the towns, the number of enterprises was more than three times the average for the Paks region. In 2019, the indicator for operating corporate enterprises per 1,000 inhabitants in the area covered by the 75 examined settlements fell short of the county average in every county, confirming the peripheral nature of the Paks region. Within the settlements located in the investigated area, the largest share of enterprises operated in the sectors of trade (19%), professional and scientific activities (15%), and construction (13%). Manufacturing activities were performed by a mere 8% of the businesses, while 7.5% of the enterprises operated in the agricultural sector. In the other activity groups, a mere 2-4% of the enterprises appeared, while the number of enterprises active in water supply, electricity, gas, steam supply, and mining was negligible. Due to the specific situation in Tolna County, the proportion of companies engaged in professional and scientific activities was outstanding, accounting for 17% of the enterprises in the 40 settlements belonging

to Tolna County, but their proportion was also relatively high in Bács-Kiskun and Fejér counties (11% and 7%).

In 2019, two-thirds (63.5%) of the enterprises in the investigated settlements were sole proprietorships, with their highest proportion recorded in Fejér County and in the villages. Another nearly one-third (32.4%) were enterprises employing fewer than 10 people, which were mostly located in Tolna County and in Szekszárd. The proportion of enterprises with 10-19 employees was a mere 2.3%, and that of enterprises with 20-49 employees was 1.2%, while the share of operating enterprises in larger headcount categories did not even reach 1%.

The key players in the local economy, the largest businesses and corporations, are present in Szekszárd, Paks, Solt, Kalocsa, and Kiskőrös (based on 2023 data). The role of the town of Paks is prominent within the investigated area because, in addition to MVM Paksi Atomerőmű Zrt., numerous other large local companies are linked to the electricity generation sector. Larger enterprises and corporations linked to agricultural activities are typical in the broader environment of the site. Among the higher value-added activities, it is mainly real estate development companies that are present in the region. Other larger local businesses and corporations are linked to industrial, construction, and food industry activities. The majority of the companies in the Paks region also engage in export activities – to varying degrees – with their number of employees ranging from a few dozen to several hundred people.

The number of employed persons in Hungary was 4.719 million, of whom 95 thousand (2.0%) lived in the investigated area. Unemployed persons, dependents, and individuals under the age of 15 represent a similar proportion within the country among the examined settlements, whereas a slightly higher share of inactive persons receiving benefits, 2.4%, lived in the investigated area in 2022. In Hungary, 45.5% of the total population is employed, compared to 44.7% within the assessment area (HCSO 2022). While 2.9% of the domestic population (237 thousand people) is unemployed, this rate stood at only 2.8% here at the time of the latest census. The proportion of inactive persons receiving benefits within the total population was 28.2%, which, on the other hand, exceeded the national average (26.2%). The proportion of dependents was 10%, similar to the national average, whereas the share of individuals under the age of 15 was 14.4%, compared to the national figure of 15.2%. In the town of Paks, the 2022 census registered 17,417 inhabitants, half of whom were employed, and only 1.7% of them (298 people) were unemployed. These indicators were even better than those of the county seat. More than a quarter of them were inactive persons receiving benefits, 8% were dependents, and the proportion of those under the age of 15 was 14.3% in 2022. In terms of its employment rate and unemployment rate, Paks ranks in the top quartile of the country's municipalities. Several other settlements belonging to the investigated area are characterized by a similarly strong employment situation (Harc, Dunatetétlen, Őcsény). In a total of 13 municipalities, at least 48% of the population is employed, and in a total of 41 municipalities, this ratio exceeded the national average of 45.5%. Among the 75 examined settlements, there are 6 where the proportion of inactive persons within the population approached or exceeded 60% (Gyönk, Nagyszékely, Kalaznó, Szakadát, Harta).

Among the 75 examined municipalities, mining and industrial activities are overrepresented in employment compared to the national average (20.8%), as 26% of employed persons work in these activities. Agricultural activity with 7.3% and construction employment with 9.2% also represent a significant weight compared to the national average (the rates of these stand at 3.7% and 7.4% on national average). Looking at the sectoral structure of the Paks region, mining and industrial activities, public administration, education, human health and social work activities, as well as wholesale and retail trade, transportation and storage, accommodation and food service activities are dominant based on the distribution of employed persons by economic sector. These three sector groups employ nearly 70% of the workforce. Within higher value-added activities, professional, scientific, technical, administrative, and support service activities account for a 7.4% share (the national average is 10%), while all other high value-added activities combined represent only an additional 7% within employment.

The economic situation of the site and its broader environment served as the baseline for forecasting the expected economic development. The projections of the European Commission (Ageing Report 2024) provided the foundation for forecasting long-term economic trends, and its

estimated results at the national level were scaled proportionally to the assessment area (primarily at the county level). The European Commission's model assumes long-term convergence, meaning that in countries where GDP per capita was below the EU average at the start of the analysed period (2022-2070), the growth rate of Total Factor Productivity (TFP) will be higher than in more advanced EU countries, allowing growth to peak in the 2040s. The model calculations assume that the further a Member State's GDP per capita lags behind the EU average at the beginning of the period, the greater its catch-up potential. In euro terms, Hungary's GDP per capita was 49% of the EU average in 2022. According to the report's calculations, the national value will increase to 54.8% by 2032 in the case of our country. Calculated at purchasing power parity, the overall picture is more favourable: Hungary reached 76% of the EU average in 2022, and historical trends show that the country approaches the average development level of the European Union (EU) by approximately one percentage point annually. If this trend continues, Hungary will reach the average level of EU development in the mid-2040s, as measured by its GDP per capita at purchasing power parity.

Fejér County started from a slightly higher level than the national average in 2022 (78%) and possessed greater growth potential, allowing it to reach the average EU development level as early as the early 2040s. Tolna County will develop from a low baseline (57%) with slow growth in the future, meaning that it could reach approximately 70% of the EU development level during this period. Bács-Kiskun County, starting from a similar development level of 58%, can progress to 75% of the EU average over the next 20 years through somewhat faster growth. Due to the aforementioned expected slowdown in convergence, the further growth performance of the region (county) remains uncertain. An uncertainty of the applied methodology is that the co-movement between the regional (county) and national growth pathways is approximately 80%, meaning that about four-fifths of a county's growth trajectory is determined by national trends, while one-fifth is shaped by its own unique circumstances. According to the assumptions of the European Commission, the annual growth rate of potential GDP in Hungary is expected to be between 1.4% and 2.5% up to 2060. This follows a continuously declining trend. Therefore, while a growth rate above 2% can be projected at the beginning of the period until 2030, this drops to 1.5% and below from the mid-2050s. The growth rate of GDP per capita is expected to be somewhat higher than this (between 2.8% and 1.5%) due to population decline. The potential GDP per employed person; i.e., the annual growth rate of labour productivity, will fluctuate within a relatively narrow band (between 1.7% and 2.5%). Similar forecasts were prepared nationwide for the future employment of the 20-64 age cohort, based on the European Commission's report.

Using the national-level projections of the European Commission, county-level GDP pathways can be estimated by following various top-down spatial downscaling methods, which are as follows (Batista-Silva et al. 2016):

A) One of the simplest methods is to distribute the projected national GDP values among Hungary's counties based on their historical average share within the national output. In this case, each county follows national trends with the same growth rate, meaning that regional inequalities do not change over the forecasting horizon.

B) One variant of this method is to calculate the estimated future GDP for each examined county based on the 2022 actual data, applying the common national growth rate. In this case, the extent of regional inequalities will not preserve its historical average size, but rather its 2022 level.

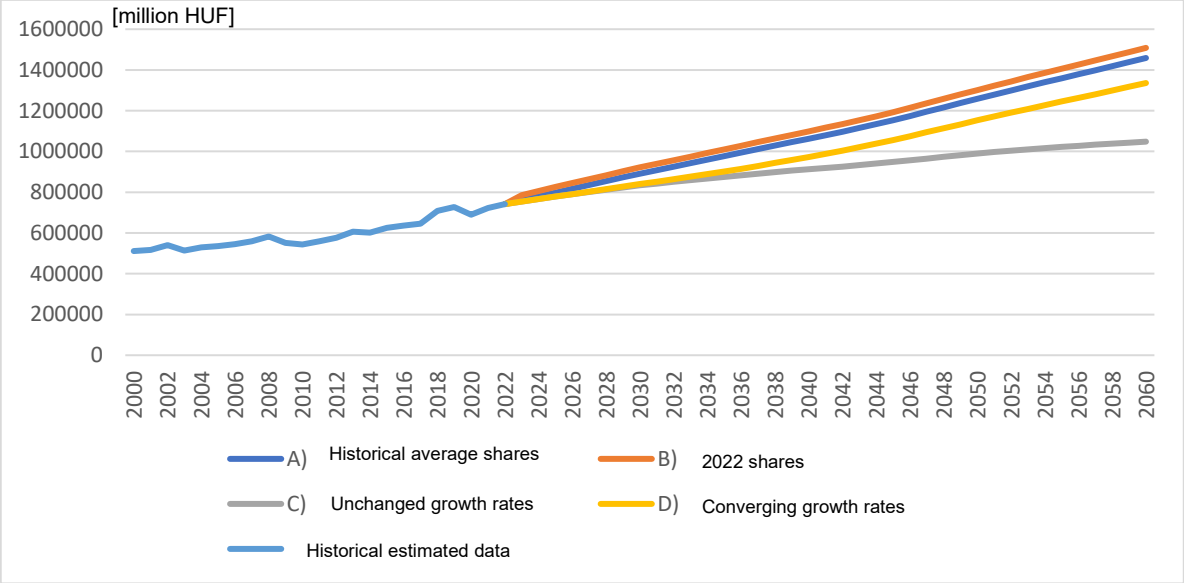
C) According to the third method, the growth of each affected county continues at the same rate as it grew in the past. Consequently, a further increase in regional inequalities can be expected.

D) The fourth variant offers an intermediate solution, combining the characteristics of variants B) and C). Its starting point is that within a relatively foreseeable period, the unique characteristics of the different counties are even more predictable. Therefore, in the first years of the forecasting horizon, it takes into account the counties' own historical growth rates with a certain – steadily decreasing – weight. Over a horizon of several decades, however, the uncertainty of the forecast increases. Therefore, the projection is assumed to be most accurate if the growth of the counties is estimated using national growth rates. This scenario

therefore assumes a convergence, a process during which the county-level growth rates approach the nationally projected growth rate. Up to 2040, the weight of the counties' historical growth rates will gradually decrease, and the national growth rate will become increasingly prominent in shaping the projected growth rate; then, from 2040 onward, the growth rate of every county will follow the nationally projected pace.

Forecasting methods C) and D) do not guarantee that the national-level GDP forecast treated as a fixed value corresponds to the sum of the projected county GDP values. Therefore, a subsequent proportional rescaling is required. This does not affect the evolution of regional inequalities. As the final step of the GDP forecasting, the county-level GDP volumes can be proportionally disaggregated among the 75 examined municipalities (based on their county-level distribution).

In the investigated area, the Paks region, growth in the period starting from the 2000s fell short of the national average on average. Therefore, the growth pathway projected according to methods A) and B) shows the most favourable picture, and the pathway C) projecting the region's own historical growth shows the most unfavourable one. Method D), assuming a growth rate converging toward the national average, projects an intermediate pathway (*Figure 4.10.2-3.*).



Source: Own compilation based on HCSO data and the European Commission 2024.

Figure 4.10.2-3. Historical estimated and forward-looking GDP pathways at constant prices in the Paks region designated by the 75 examined settlements (2000-2060)

According to estimates, the projected GDP per capita is expected to show a 2.5-fold increase nationally in the long term, calculated at constant prices between 2022 and 2022. Within the Paks region, three methods project a higher growth of 2.6 to 3.1 times, while according to the most pessimistic scenario, this growth will be only 2.1-fold. The projections prepared using multiple methods show a gradual convergence toward the national average, the main driving force of which is the expected decline in population, as it results in an increase in GDP per capita.

Based on the different conditional scenarios, no significant reduction can be expected in the cross-sectional disparities of regional development (relative cross-sectional standard deviation) within the Paks region, according to the long-term economic forecast. If the historical growth performance of the counties is projected into the long term, a further increase in regional disparities is expected.

The spatial dispersion of GDP per capita heavily tracks the regional patterns of labour productivity, as the inter-county differences in employment rates and particularly in demographic indicators are much smaller than in labour productivity. The long-term labour productivity pathways estimated by various methods show that the productivity of the Paks region is expected to remain below national levels, and over time, the extent of this shortfall will increase to a greater or lesser

degree. While the projected nationwide productivity is expected to see a 2.22-fold expansion between 2022 and 2060, the productivity of the Paks region estimated by different methodologies could grow 1.59 to 2.29 times over the same period.

According to the European Commission's (2024) estimates, employment growth will gradually slow down after 2025 and shift into a decline from 2029 onwards, as even the rising employment rate will be unable to offset the shrinking of the working-age population. In the Paks region, the number of employed persons stood at 95.1 thousand in 2022. According to the projection, employment will reach its peak in 2028 (97.6 thousand people) and then gradually fall back from this level by approximately 14% to 84.3 thousand people by 2060 in the investigated area. While the projections suggest that the employment rate of the 20-64 age group could increase from 80.3% to 83.7% between 2022 and 2060, a very significant decline is expected in the number of the working-age population: the proportion of the working-age population will decrease by about 33% nationally and by 45% in the 75 examined settlements in the future.

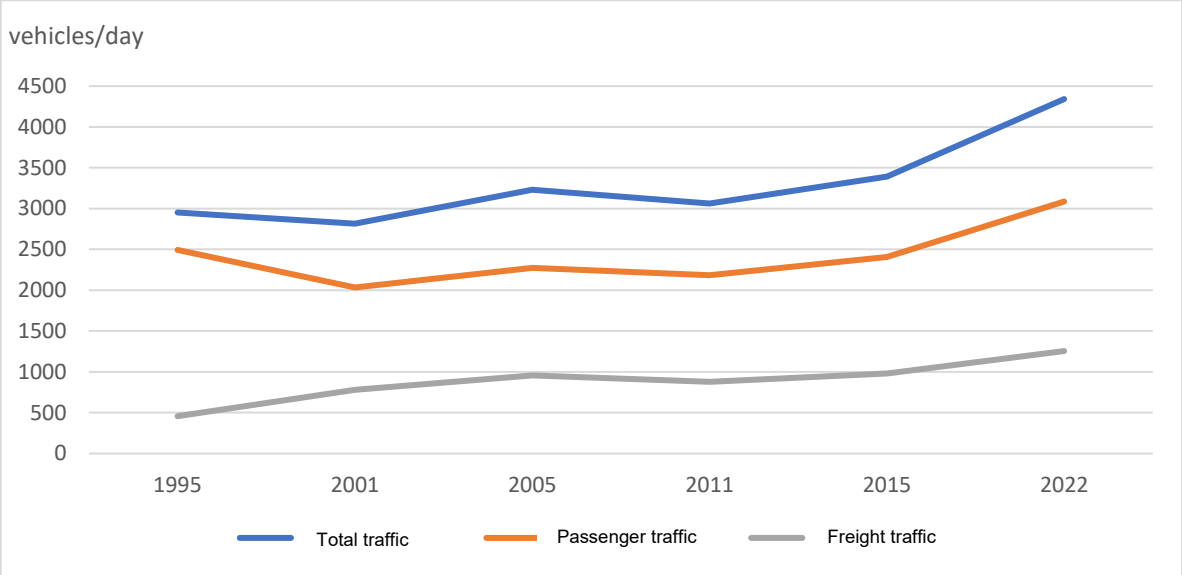
4.10.3.Transport situation and future forecast of the site and its broader environment

The presentation of the transport situation – partially by main sectors – was carried out based on the traffic data available for all vehicles between 1995 and 2022 on the affected road sections (within the area of the Paks region). In addition, the commuting data provided by the census also serve as information carriers for social and economic consequences. While the statistical data analysis for transport is suitable for presenting the investigated area as a whole, a limiting factor of the method is that it is not adequate for municipal-level examinations.

Based on the length of the railway network, rail transport changed between 2007 and 2023, primarily in Tolna County, which is the most affected. Affecting the area of the examined Paks region, this was mainly the 2009 branch line closure, during which the length of railways in use decreased by 13% from 2009 to 2010 (from 237 km to 206 km), essentially through the decommissioning of the Paks-Mezőfalva line.

Tolna County plays a primary role in the road transport of the site and its broader environment, as 31.5% of its current road network touches the investigated area (compared to 6.8% in Bács-Kiskun County and 0.6% in Fejér County). The road network in Tolna County was 1,072 km long in 2000 and 1,087 km in 2009, but the opening of the M6 motorway in 2010 increased this to 1,216 km, finally adjusting to 1,221 km by 2023. In addition to the 65 km section of the motorway (82.6 km including the junction ramps), the main road network has already expanded by 12% in Tolna County. Based on data from Magyar Közút Nonprofit Zrt. (Hungarian Public Road Nonprofit Ltd.), it can be established that secondary roads accounted for 63% of the total constructed roads between 2005 and 2023, and the motorway itself constitutes 7.2% of the county's road network. Road traffic in the Paks region expanded continuously between 1995 and 2022 (*Figure 4.10.3-1.*). This represented a milder increase between 1995 and 2001, and a more significant 42% growth in traffic between 2011 and 2022.

Macroeconomic crises, including the 2008/2012 global crisis and the 2020/2022 COVID-19 pandemic, caused temporary setbacks in traffic growth. Average daily traffic rose from 3,000 vehicles in 2011 to over 4,300 in 2022, with growth exceeding 40% for both passenger and freight vehicles. The reasons for this include the economic recovery and the opening of the M6 motorway. The daily traffic on the M6 itself grew more steeply than that on the roads of the Paks region in general. The value, which stood at 6,974 vehicles/day in the starting year, increased to 11,681 vehicles/day over 11 years. The average of the measurement points on the M6 motorway within the investigated area showed a 50% increase in traffic between 2011 and 2021. Otherwise, the intensity of road traffic in the Paks region stagnated between 2001 and 2011, and then expanded by 7% between 2011 and 2021 (excluding the traffic measured on the M6). It should be emphasized that the measurement points in the Paks region are located on only Main Road No. 6, eight secondary roads, and six connecting roads. Therefore, the analysis results can be interpreted with certain limitations. It should be noted that in the site and its broader surroundings, the development of total traffic was determined by passenger transport on public roads during the examined period between 1995 and 2022.



Data source: Magyar Közút Nonprofit Zrt.

Figure 4.10.3-1. Development of road traffic in the Paks region (1995-2022)

In the site and its broader environment, only the Danube is suitable for significant water transport, and Paks is the only location with a port. The PaksPort operates as an intermodal logistical center, and the port offers various logistical and transshipment services. Besides the Port of Paks, the closest ports to the investigated area are Baja, Dunaújváros, and Mohács. It can be assumed that there may be significant freight traffic (even by road) between the northern Port of Dunaújváros and the southern ports of Baja and Mohács, and this transit traffic affects the investigated area. No major airport is located in the Paks region, and the role of air transport is negligible.

Commuting has a fundamental impact on the development of transport characteristic of the Paks region, as daily commuting is an important component of traffic dynamics. A significant part of the traffic results from the movement of passenger cars and buses; i.e., daily passenger transport, which is why it was justified to examine the commuting habits of the Paks region. According to the latest 2022 census, a total of more than 50,000 people participated in daily commuting across the 75 examined settlements, which can involve very different distances. A portion of the commuters arrived from municipalities outside the region (11,862 people), but the majority of commuters (21,530 people) had both their residence and workplace in different settlements within the Paks region. In the case of Paks, located in the center of the region, only 20% of in-commuters (1,230 people) arrived from outside the region. Furthermore, they transit through the Paks region, meaning that significant traffic can be attributed to their commuting to work. The two most important settlements from a commuting perspective are Szekszárd and Paks. Between 2001 and 2022, the proportion of commuters increased by 48.4% in the former and by 95.3% in the latter.

On a national average, approximately one-third of employed persons live and work locally, while two-thirds commute to work in other municipalities. Within the investigated area, the proportion of employees commuting to another settlement is similar to the national level (50%) in the villages, whereas it stands at 59% in the large villages, 38% in the towns, and 23% in the county seat. In the town of Paks, 86% of employees live locally, and a mere 14% commute to work in another municipality. The number of locally employed persons in Paks was 13,856 at the time of the 2022 census, while the number of employed persons living and working locally was 7,512. A total of 1,232 people commuted to work in other municipalities, while the number of daily in-commuters stood at 6,344.

The long-term forecast of transport – lasting until 2060 – was based on daily traffic count (passenger and freight traffic) data. The method applied was long-term time-series statistical observation; i.e., trend calculation, during which annual data were aggregated and extrapolated (forecasted) for 2030, 2040, 2050, and 2060. Analytical trend calculation generally expresses the underlying direction (trend, tendency) in a time series using a regression function, thereby fitting

a trendline to the time series. Ultimately, in the regression analysis, the explanatory variable was the time factor t itself. Extending the linear trendline aided in short-, medium-, and long-term forecasting (10, 20, and 30 years ahead). The transport forecast was prepared by extending the trendline emerging from the existing statistical data, but special attention must be drawn to the limitations of the prognosis. As a starting point, only those years for which data are available can be considered (e.g., from 1995 or 2005 to 2022; i.e., over a span of 28 or 18 years). Therefore, forecasting for more than 30 years into the future can only be based on these, which in itself is a limiting factor.

The linear trendline fitted to the traffic data (total, passenger, and freight traffic) examined between 2005 and 2022 not only provides information about the historical transport situation and its changes, but its extension up to 2060 can also provide forecasts for the future development of transport in the Paks region. Accordingly, the trendline emerging from the 18 examined years shows that traffic growth will continue here in the long term as well. However, this prognosis must also take into account that 1) there may be economic crises between 2022 and 2060, which are always followed by a recovery, 2) there will be further motorway constructions in the region in the future as well (currently, the M9 is the planned motorway), 3) remote work ("home office") could become widespread in the future. These factors, in turn, may rather moderate the growth of traffic, even if temporarily.

Looking toward the long-term future, within total traffic, the role of freight transport in particular will grow more significantly up to 2060 (*Table 4.10.3-1.*). The average of 4,300 vehicles/day measured in the year 2022 will increase to over 5,700 vehicles/day by 2060. In total, this could represent a 32% increase over 38 years, which, on the other hand, is a lower rate of growth than what was experienced over the 28-year period between 1995 and 2022 (47%). Obviously, it must also be factored in that the M6 motorway was opened in 2010. Looking to the future, it must be taken into account that the impact of the M6 motorway will diminish over time as its capacity utilization stabilizes. Also looking ahead, the expected impacts of the Tomori Pál Bridge, opened to traffic in 2024, must be considered, in connection with which an expected increase in traffic can be anticipated between Kalocsa and Paks, although its magnitude is currently difficult to estimate.

Table 4.10.3-1. Prognosis for the development of road traffic in the Paks region, 2030-2060

Traffic type	Vehicles/day			
	2030	2040	2 050	2060
Total traffic	4 326	4 796	5 267	5 737
Passenger traffic	2 901	3 124	3 346	3 569
Freights traffic	1 426	1 674	1 922	2 169

4.10.4.Summary of anticipated socio-economic impacts

The demographic processes characteristic of the site and its wider environment align with national trends; population decline, a negative net migration balance, and an aging population have fundamentally determined the population change of the examined municipalities for decades. At the same time, Paks exhibits a more favourable position in certain aspects, based on a younger age structure and higher educational attainment at the county level, or a higher household employment rate and higher per capita income at the national level.

Current demographic processes heavily influence the results of demographic projections, based on which the continuation of existing population trends is likely until 2062. However, the rate of population decline will be more intense than the national average under all three scenarios. Over the long term, population change within the Paks region is expected to be accompanied by characteristic territorial disparities. The city of Paks is anticipated to retain a more favourable labour-attracting capacity in the future, which, uniquely within the investigated area, will positively impact its demographic outlook compared to its surroundings. Based on the projections, the age structure of the population will also undergo a significant transformation within the investigated area by 2062. While the proportion of young and active age groups will shrink by half, a substantial

increase in the share of the oldest age groups is expected over the long term due to rising life expectancy, which may be accompanied by a significant shift in the old-age dependency ratio. The quantitative change in population and the transformation of the age structure will occur alongside the persistence of territorial disparities over the long term. However, Paks and Szekszárd will possess the most favourable age structures, as they will remain potential target municipalities for employees in the future.

The demographic situation can 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 wider environment is approximately three-quarters of the national average. A significant economic center-periphery divide exists among the 75 municipalities examined, which is supported by several indicators. The 8 municipalities belonging to Fejér County significantly lag behind the average development level of the county, which is high even in a national comparison. Although the disparities are smaller in Bács-Kiskun County, the 27 municipalities located there – with the exception of a few towns – are less developed than the rest of the county. The distance isolates this area from the positive spillover effects of Kecskemét, while the Danube cuts it off from the spatial spillover effects of Paks. In Tolna County, thanks to the NPP, Paks is considered one of the main economic power centres among the 40 municipalities, with its economic indicators often surpassing even those of Szekszárd, the county seat. Economic dynamism in the region remains subdued, as sectoral specialization does not provide a stable foundation for long-term growth. Based on long-term economic forecasts and various conditional scenarios, no significant reduction is expected in the cross-sectional disparities of regional development. Projecting the past growth performance of the counties into the long term, a further increase in regional disparities is expected. Paks and its immediate vicinity demonstrate an economic performance that is superior to the national average, but its local spillover effects are realized only within a limited area.

Regarding the transportation of the site and its wider environment, it is important to highlight the role of the M6 motorway and the bridge between Kalocsa and Paks in road traffic. In addition, transit traffic through the investigated area is also significant; specifically, the rising number of out-commuters from the Paks region, in-commuters from outside into the region, and intra-regional commuters has been continuous for over the past twenty years. All of this occurred against the backdrop of a declining population, meaning that the significance of spatial mobility intensified even as population numbers decreased both regionally and nationally. Based on commuting patterns, a marked territorial concentration can be observed, with every third commuter working in Szekszárd and every sixth in Paks. Based on current transport infrastructure development plans, an increase in road traffic is anticipated within the examined Paks region, to which the growing freight and passenger vehicle traffic associated with the construction of Paks II NPP may also contribute in the future.

The social and economic consequences identified during the investigations project that no substantial transformation is expected in the long term within the 30 km radius geographical environment around the Paks NPP. The SSLE of the NPP and the associated environmental impacts will not result in a significant change in existing processes, trends, and phenomena. The use and usability of the areas affected by the environmental impacts of the NPP are not expected to be influenced by the implementation of the SSLE, given that it concerns the extension of the service life of a facility that is currently in operation. Thr social-economic impacts resulting from land-use change (e.g., the loss of jobs or income sources for farmers due to the conversion of previously cultivated agricultural land to industrial use, or due to agricultural cultivation becoming impossible as a result of the environmental impacts of the planned activity, leading to a transformation of the employment structure and income conditions) are fundamentally not expected. An exception to this is the land-use change of the Danube bank section affected by the short segment of the alternative warm-water channel outside the power plant site, where a portion of the forested area will be converted to industrial use. The utilization of the forested area is an issue to be examined primarily from the perspective of biosphere and ecosystems, which is addressed in *Chapter 4.5*. Substantial socioeconomic impacts are not anticipated in this case either. Furthermore, the modification planned for the SSLE of the NPP can be considered of overriding public interest.

The current quality of life level of the population in the region affected by the environmental impacts of the NPP will not change significantly. The social and economic processes experienced at present are not anticipated to result in a turning point or a large-scale change by 2060.

Overall, the main finding of the technical investigations is that, regarding social and economic consequences, the SSLE until 2052-2057 maintains the current situation in the immediate and wider environment of the site (e.g., in terms of employment, quality of life, economy, etc.), and a significant change would occur precisely if the Paks NPP were to shut down in 2032-2037, as the current impacts would then cease.

5. Characterization of the environmental radioactivity and expected changes due to the extension of operational life

5.1. Emissions of radioactive materials from the Paks NPP

5.1.1. The current emissions of radioactive materials from the NPP

During the operation of the Paks NPP, radioactive materials are released into the atmosphere and to surface water (the River Danube). The essential difference between gaseous and liquid emissions is that while gaseous emissions and their control are continuous, radioactive wastewaters of various origins are collected in tank-parks at the power plant and, following preliminary control, are released intermittently. Thus, in the case of liquid emissions, this allows further operational intervention (retention, concentration, dilution, etc.).

The main sources of airborne radioactive materials in the NPP are as follows:

- organized and unorganized leaks of primary circuit coolant,
- leaks of the evaporators' systems, leaks of the contaminated condensate tank water, leaks of the cooling pools water,
- water sample tests performed in express laboratories in the main building,
- radioactive gas mixture released from the hydrogen burner,
- leaks and overflows of the water purification systems and liquid radioactive waste storage systems in the auxiliary building,
- in the healthcare building, the hot chamber complex of metal technology and water chemistry, the chemical chamber in the corridor of the hot chambers' row, the ICP (inductively coupled plasma) emission spectrometer for analysing primary circuit water samples, the chemical chambers for chemical measurements, the chemical cabins for dosimetry preparation.

The air extracted by the ventilation systems from the potentially contaminated rooms of the NPP and from the technological blow-downs is released through various filter systems (aerosol, iodine). The release points of gaseous radioactive materials in the NPP are as follows:

- Ventilation chimney of Units 1-2 (height 100 m):
  The nominal air volume released into the environment is approx. 567,000 m^3/h in the normal operational state of the Units and approx. 686,000 m^3/h during maintenance of one of the Units. Of the total air volume, approx. 142,000 m^3/h is air filtered by the gas purifiers of the exhaust systems, the remaining amount is inactive air.
- Ventilation chimney of the healthcare building (height 30 m):
  The nominal air volume is approx. 164,000 m^3/h, of which 4,500 m^3/h is the air extracted from the chemical booths of the radiochemistry laboratory, approx. 3,400 m^3/h is the air extracted from the hot-chamber row, and 5,000 m^3/h is other air released after filtration.
- Ventilation chimney of Units 3-4 (height 100 m):
  The nominal air volume released into the environment is approx. 570,000 m^3/h in the normal operational state of the Units and approx. 690,000 m^3/h during maintenance of one of the Units. Of the total air volume, approx. 134,000 m^3/h is air filtered by the gas purifiers of the exhaust systems, the remaining amount is inactive air.

The main sources of liquid radioactive waste in the NPP are as follows:

- emptying and de-aeration of the technological systems,
- the exhausted decontamination solutions from decontaminations required during planned maintenance of the power plant,
- the decontamination solutions entering into the special channel in course of decontamination of rooms, unorganized leaks (through the special channel),
- the regenerates and loosening waters of primary circuit water purifiers,
- the exhausted ion exchange resins,
- the acidifying solutions used for cleaning of evaporators,
- the radioactively contaminated laundry waters,

- the wastewater from radiochemical laboratories,
- the radioactively contaminated solvents and oils resulting from surface cleaning and from other activities,
- radioactive wastewater resulting from cleaning of fuel assemblies,
- wastewater generated in course of the transfer of spent fuel assemblies to the SFISF.

The above-listed wastewaters are evaporated after their collection, sedimentation, temporary storage and pre-treatment (except for those that are stored directly as liquid radioactive waste in auxiliary buildings).

The appropriately pre-treated wastewaters with a salt content of about 3-5 g/l are concentrated in the evaporator. The distillate from the evaporators, following condensation and passing through mechanical filters and appropriate radiochemical control, is directly transferred to the control tanks, or if radioactive contamination is detected during the control, it is transferred to the control tanks via cation and anion exchanging filters. After the chemical and radiochemical control, the purified condensate is either discharged as excess water or is transferred to the tanks used for the supply of clean condensate to the power plant's in-house operations, provided that it meets the prescribed standards. In the case if the condensate does not meet the required standards, it is returned to tanks of leaks-waters for recycling.

The above-balance and wastewaters generated during the operation of the NPP are collected in control tanks before their discharge. In all cases, the discharge of the waters is preceded by strict chemical and radiological qualification. The detailed requirements for the discharge of wastewaters (activity, pH, discharge route) are contained in the currently valid “Water Discharge Regulations”.

The amount of radionuclides that can be discharged is regulated by strict authority limits, the compliance with which it is repeatedly checked by the power plant itself and the authorities. From the very beginning, the operator of the Paks NPP implemented a broader range of emission control than required by authority regulations. First of all, it has expanded the scope of nuclide-specific tests, which is also of fundamental importance for the calculation of the radiation exposure of the population. The results of the emission control are summarized by MVM Paksi Atomerőmű Zrt. in monthly, quarterly and annual reports.

The currently effective emission limitation system prescribed by Ministerial Decree 15/2001. (VI. 6.) KöM on radioactive emissions into air and water in course of the use of nuclear energy and their control, isotope-specific emission limits derived from the dose constraint specified for the NPP (90 μSv/year) apply to both liquid and gaseous emissions. The aggregated emission data for the year 2024 characterizing the normal operational radioactive emissions of the NPP and the corresponding so-called emission limit value criterion utilizations are grouped in *Table 5.1.1-1*. The normalized values of the radioactive substances emitted from the NPP per unit of electricity generation are shown in *Table 5.1.1-2*.

In summary, it can be said that the NPP has complied with the limits on radioactive emissions in all aspects with a large margin in course of its entire operating period. The power plant utilized the emission limit by 0.33% in 2024 (emission limit criterion utilization: $3.26 \cdot 10^{-3}$), of which 0.242% was for liquid emissions, while 0.08% was for gaseous emissions. The utilization of the emission limit criterion in previous years – in 2019 it was 0.28%, in 2020 was 0.30%, in 2021 was 0.38%, in 2022 was 0.084%, and in 2023 it was 0.37%, so the utilization of the limit in recent years was of a similar magnitude.

Based on the evaluation of the results of the nuclear environmental monitoring in 2024, it can be stated that the operation of the NPP did not have a directly measurable impact on the radiation conditions of the environment in 2024 either. The dose rate measuring probes of the “A” and “G” type stations, as well as the measurement results of the TL detectors placed at all measurement stations, showed dose rates and doses typical of natural gamma radiation in the environment.

Table 5.1.1-1. Summary data on annual radioactive emissions from the NPP in 2024

Isotope-groups	Total emission [Bq/year]	Utilization of the emission limit
Airborne emissions		
Corrosion and fission products	$6.10 \cdot 10^{8}$	$9.30 \cdot 10^{-5}$
Radioactive noble gases	$2.70 \cdot 10^{13}$	$4.12 \cdot 10^{-4}$
Radioiodines (^{131}I equivalent)	$8.98 \cdot 10^{7}$	$1.36 \cdot 10^{-5}$
Tritium	$4.09 \cdot 10^{12}$	$2.35 \cdot 10^{-5}$
Radiocarbon	$7.81 \cdot 10^{11}$	$2.94 \cdot 10^{-4}$
In total:		*$8.36 \cdot 10^{-4}$*
Liquid emissions		
Corrosion and fission products	$1.02 \cdot 10^{9}$	$8.91 \cdot 10^{-4}$
Tritium	$2.79 \cdot 10^{13}$	$9.61 \cdot 10^{-4}$
Radiocarbon	$1.76 \cdot 10^{9}$	$5.69 \cdot 10^{-4}$
Alpha emitters	$6.28 \cdot 10^{5}$	$8.48 \cdot 10^{-7}$
In total:		*$2.42 \cdot 10^{-3}$*

The emission limit criterion is the ratio of the emission limit to the quantity emitted for a given isotope and emission method, which is calculated as:

$$\sum_{ij} \frac{R_{ij}}{El_{ij}} \leq 1$$

where:

El_{ij} – emission limit value for radionuclide *i* for emission mode *j* (Bq/year),
R_{ij} – annual emission of radionuclide *i* for emission mode *j* (Bq/year).

Table 5.1.1-2. Values of radioactive materials emitted from NPP normalized to unit electricity generation

Radionuclide	Paks NPP [GBqGW$_e^{-1}$year^{-1}]	
	2024	**1983-2024**
Airborne emissions		
Corrosion and fission products in aerosols	$3.5 \cdot 10^{-1}$	$6.5 \cdot 10^{-1}$
^{131}I equivalent	$5.2 \cdot 10^{-2}$	$1.1 \cdot 10^{-1}$
Total noble gases	$1.6 \cdot 10^{4}$	$1.2 \cdot 10^{5}$
Total tritium*	$2.4 \cdot 10^{3}$	$2.1 \cdot 10^{3}$
Total radiocarbon**	$4.5 \cdot 10^{2}$	$4.8 \cdot 10^{2}$
Liquid emissions		
Corrosion and fission products	$5.9 \cdot 10^{-1}$	$1.5 \cdot 10^{0}$
Tritium	$1.6 \cdot 10^{4}$	$1.1 \cdot 10^{4}$

* Average of 1985-2024.

** Average of 1988-2024.

The estimated average annual increase in the River Danube's water due to radioactive materials released into the River Danube – following the complete mixing-up – was less than 1.0 Bq/dm^3 for tritium and less than 0.1 mBq/dm^3 for all other radionuclides taken together.

In relation to the direct appearance in the environment of the emitted radioactive isotopes, according to the experience – even based on very sensitive testing methods – no isotopes of artificial origin could be detected in the near-surface air samples at a distance of 1-2 km from the power plant at the A-type stations. The radiocarbon has a value of around 40 mBq/m^3, tritium is in the order of 10-20 mBq/m^3 (in the case of A3 and A4 stations it is mostly 10-400 mBq/m^3), and the activity concentration of radioactive noble gases in the environment can be estimated at

around 100 mBq/m^3 at the same locations. No artificial isotopes of NPP origin were detected in the fall-out samples in course of the year.

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

Based on the usage of the emission limit value criterion, we can conservatively estimate the dose affecting the population, and this estimated value has been confirmed by the calculation of the effective dose of the critical population group performed using modern propagation calculation methods. Based on the dose exposure of the population resulting from normal plant operation (50-100 nSv committed effective dose), it can be stated that the very strictly defined emission limit values have been selected appropriately and ensure that the 90 µS/year dose constraint for the NPP and thus the public dose limit are largely met.

Based on the Preliminary Consultation Document, the Baranya County Government Office, in its opinion concluding the preliminary consultation, stipulated in item II. 4.1 that the user of the environment *"Shall declare whether it intends to continue to apply the atmospheric and liquid emission limit values derived from the dose* constraint *of 90 µS/year determined so far. Furthermore, it shall submit the document, as an annex to the environmental impact assessment, on the determination of the emission limit values for Units 1-4 of the Paks NPP."*

The MVM Paksi Atomerőmű Zrt., as the operator of Paks NPP, intends to continue, in accordance with the emission information presented above, to apply the atmospheric and liquid emission limits derived from the 90 µS/year dose constraint.

This – maintaining the current value of the dose constraint – is also justified by the following two aspects. In addition to the values derived from the 1 mSv dose constraint, which are currently 90 µS/year for Paks NPP and Paks II NPP, and 10 µS/year for PURAM, it would be possible to correct the values by increasing them.

Based on the dose limit and the number of facilities on the Paks site, the dose constraint n of all three licensees could be 100-100 µS/year, even in the case of the SFISF. In addition, a potential, applicable only for the Paks NPP modification request would entail the question of why this value would be different in the case of the Paks II NPP. Especially, if taking into consideration that an important aspect in choosing the dose constraint for the Paks II NPP was that it should be synchronous with the dose constraint for the Paks NPP. In addition, an even more important aspect is that according to the ALARA principle applied in the field of radiation protection, the level of radiation exposure should be as low as reasonably achievable. Thus, increasing the current low value would not be acceptable for this reason either.

Therefore, based on our current knowledge, there is no reason for modification of the limits for atmospheric and liquid emissions. In relation to the future, in the case of fuel assemblies to be manufactured by Westinghouse, which should be taken into consideration as part of the fuel diversification process, which is currently only in the preparatory phase, it may be appropriate to modify the range of isotopes controlled by the limit value. As the necessary analyses will be carried out in a later phase, this can only be determined precisely once the calculation results are known. However, it can already be stated, based on the preliminary analyses carried out so far, that these possible modifications will not jeopardize compliance with the dose constraint value, and will not change the extremely low utilization factor in comparison with this value, so they will not result in a significant change in environmental impact.

As a result of the unchanged consistency of the limit values for atmospheric and liquid emissions, the following documents submitted to the environmental protection authority and accepted by the authority as a basis for these remain valid, so they have not been attached to the present EIAR as an annex:

- Letter No. OTH 40-6/1998 on the determination of dose constraint for the critical population group of the Paks NPP and the SFISF, OTH, 1998.
- Determination of the emission limits of the Paks NPP, OKK-OSSKI, Budapest, March 2003.
- Determination of the emission limits of the Paks NPP, Supplement, OKK OSSKI, Budapest, September 2004.
- Extension of the radioactive emission limit, Assessment, Determination of the emission limits of the MVM Paks NPP for the isotopes ^{108m}Ag and ^{159}Gd, version 2 (4000053668), OSSKI, February 2014.

5.1.2. Anticipated emissions of radioactive materials in course of the period of further extension of the operational lifetime

The radioactive emissions of the Paks NPP, taking into account the current operating characteristics, will not change in course of the period remaining until the end of the currently licensed operational lifetime and neither then in course of the SSLE period, since no such changes are planned in relation to the SSLE regarding the technology, or operational characteristics of the NPP that would significantly affect the characteristics of the radioactive emissions. Accordingly, it can be said that the current radioactive emissions presented in *Chapter 5.1.1.* are expected to be characteristic in course of the SSLE period as well. This means that the characteristics, quantity and method of gaseous and liquid radioactive emissions are not expected to change compared to the current state.

Taking into account the experience so far, it can be stated that in course of operation of the extended lifetime of the power plant, the magnitude of gaseous and liquid radioactive emissions will remain in a similar range to that it used to be. The continued operation of the Paks NPP will therefore not entail a greater radiological risk than before.

5.2. Characterization of environmental radioactivity

5.2.1. Results of the radiological environmental monitoring of the NPP

Based on the annual reports prepared by MVM Paksi Atomerőmű Zrt., presenting its radiation protection activities, as well as the comprehensive processing of authority measurements for the period 2011-2023, the following conclusions can be made regarding the radioactivity measured in the vicinity of the NPP site.

Based on the results of measurements of the gamma-emitting isotopes presented in the reports, it can be stated that, with the exception of a few cases, the values obtained in each year either remained below the 1980 baseline level or were very similar to those measured at the reference station located 30 km away or to the countrywide measurement values. Activity concentrations above the detection limit related to the NPP occurred only a few times in air, fallout, soil and fish pond sludge samples.

Regarding artificial isotopes (e.g. ^{131}I, ^{134}Cs, ^{137}Cs), the deviations can be primarily attributed to the 2011 Fukushima accident and the Hungarian, domestic emissions that occurred also in 2011 in course of isotope production. The observed increases in ^{90}Sr and ^{137}Cs are not contributions from the Paks NPP, but are presumably consequences of the Chernobyl accident.

There are no national measurement data available for the tritium (^{3}H) and radiocarbon (^{14}C) content of the air (since such measurements were only performed by the KEL laboratory of the Paks NPP), therefore in this case the B24 measuring station, located 30 km from the power plant, was selected as the reference. The results obtained showed good agreement between the “A” type stations and the B24 measurement station.

The average ^{3}H activity concentration in the sampling wells within the power plant site showed a continuous decrease. The measurement results from the wells outside the site correspond to the ^{3}H activity concentration in the surrounding fish ponds and in the River Danube. No artificial gamma-emitting isotopes originating from the power plant above the detection limit were not detectable.

The environmental dose rate values showed a good agreement with the baseline and Hungarian national average values. The increase, originating from the power plant, was not detectable.

In addition to the processing of measurement data from 2011-2023, in situ gamma spectrometry and environmental dose rate measurements were carried out at 5 different locations in the vicinity of the NPP in 2024, as well as laboratory tests were performed on soil and plant samples collected on a monthly basis. Following the measurements, the test results were systematized and analysed using statistical methods, and compared with the baseline values.

In 2024, the environmental dose rate values showed a trend corresponding to the baseline value, which confirms that there is no increased dose rate level in the vicinity of the NPP.

In the soil samples examined in 2024, the activity concentration values for the ^{238}U-series elements (^{214}Pb and ^{214}Bi) and the ^{232}Th-series elements (^{228}Ac and ^{212}Pb) were between 29-34 Bq/kg, with an average of 31 Bq/kg at 4 out of 5 sampling locations. The only significant differences were observed in the soil samples from sampling point 4, located 0.9 km south of the power plant site, which had an average activity concentration of only 12-14 Bq/kg. The results obtained in course of the laboratory examination of the soil samples showed good agreement with the values measured by in situ gamma spectrometry.

The ^{40}K activity concentration of soil samples were also the lowest at sampling point 4 (average 292 ± 9 Bq/kg) in 2024, while the average values of samples taken at the other sampling points were between 419 and 535 Bq/kg. The ^{40}K activity concentration of plant samples ranged from 60 to 386 Bq/kg based on the mass of the original material (or 63 to 1477 Bq/kg based on dry matter).

The ^{7}Be activity concentration values ranged from 0.75 to 8.47 Bq/kg in soil samples, while that of plant samples ranged from 15 to 279 Bq/kg based on dry matter (4.55 to 152 Bq/kg based on original mass) in 2024.

The value of the total β-activity concentration measured in soil and plant samples (soil: 316-698 Bq/kg, plant: 105-1699 Bq/kg on dry matter) showed good agreement with the ^{40}K activity concentration in them, which suggests that the majority of the measured total β-activity originated from the ^{40}K isotope.

The ^{137}Cs activity concentration of the soil samples in 2024 ranged from 1.25 to 23.2 Bq/kg. The measured ^{90}Sr activity concentration ranged from 0.28 to 2.38 Bq/kg and was typically lowest in the samples taken from sampling point 4 (in average 0.436 ± 0.14 Bq/kg). The test results fell within, or were below the 1980 baseline range, with the exception of the samples from sampling point 5 (mainly the spring ones), located 3.4 km northeast of the site. The ^{137}Cs activity concentration at sampling point 5 was higher in every month compared to the other 4 sampling locations (in average 17.81 ± 3.06 Bq/kg). The lowest values of ^{137}Cs activity concentration were typically measured in soil samples from sampling point 4 (in average 2.12 ± 0.67 Bq/kg). The undisturbedness of sampling point 5 was also confirmed by the ^{137}Cs distribution results of the deep soil samplings preceding the in-situ gamma-spectrometry studies.

The ^{137}Cs activity concentration values of the plant samples ranged from <0.032 to 0.49 Bq/kg on dry matter in 2024, while the measured ^{90}Sr activity concentration values ranged from 0.223 to 4.44 Bq/kg (on dry matter). The test results were in all cases within, or below the 1980 baseline range. No close correlation between the measurement results and the sampling locations could be proven. The only significant difference was only detected in the average activity concentration values of the different types of plant samples in terms of the ^{90}Sr activity concentration (pasture grass: 0.560 ± 0.149 Bq/kg (on dry matter), nettle: 2.260 ± 0.821 Bq/kg (on dry matter)).

In summary, it can be stated that neither the data processing carried out for the years 2011-2023, nor the results of the on-site and laboratory tests in 2024, showed any excess radiation exposure to the population and the environment from the power plant during its normal operation. The detailed description of the results of the radiological environmental monitoring can be found in *Annex 11*.

5.2.2. Impacts of the NPP operation on radioactivity of the environment

5.2.2.1. Impacts of the stand-alone operation of the Paks NPP

The results of the radiological monitoring of the Paks NPP environment for the period 2011-2023 were processed in detail within the framework of the implementation of the study programs that provide the basis of the SSLE EIA. In order to monitor continuously the radiation level of the environment, not only the Paks NPP's own environmental monitoring laboratory carries out tests, but also authority laboratories monitor the activity concentration of various environmental media. It was possible to establish that the level of the background radiation in the environment of the Paks site during the period of the investigation fell within the same range as the national typical data. Radionuclides of artificial origin originating from the NPP were detectable only in a few cases in environmental samples.

The investigations were related to the normal operational emissions of the power plant. The investigations carried out before the first extension of operational lifetime of Paks NPP also provided similar results, and they were also carried out for normal operational emissions. Assuming that the normal operational emissions of the power plant remain within similar ranges as those were previously, it can be assumed that the continued stand-alone operation of the Paks NPP does not pose a greater radiological risk to the environment than before.

5.2.2.2. Combined impacts of the operating and planned nuclear facilities

According to the construction license documents of Paks II NPP, the NPP was designed in such a way that the level of radioactive radiation to the environment and the population in course of the continuous normal operation of the units and expected operational events, will not exceed the dose limits for population, nor the radioactivity of the environment. In order to verify this, dose calculations were performed concerning the impact in the course of operation of Paks II NPP in the vicinity of the site. The results obtained are completely similar to the calculation results for the case of normal operational emissions of the Units of Paks NPP.

In the course of the examination of the expected impacts on the environment during normal operation of the Paks II NPP, the calculations showed that the doses anticipated to be imposed on the population in the course of normal operation of the two units of Paks II NPP from gas-aerosol emissions and liquid emissions, are significantly lower than the dose constraint of 90 μSv/year established for the facility on its own. Furthermore, the dose resulting from the actual emissions will be much lower than this value.

The designs of the power plant also describe in detail how the environmental and radiation monitoring system of Paks II NPP will cooperate with the emission and environmental radiation protection monitoring system of the existing units, i.e. the Paks NPP. In order to achieve the most appropriate territorial coverage, the existing measurement stations will need to be relocated in some cases and to build new ones in some other cases.

Based on the above, it can be stated that in course of the common operation of the Paks NPP already operating on the site and the Paks II NPP, being now under construction in the course of normal operation of a NPP, will be negligible from the point of view of the anticipated environmental radiological exposure.

5.3. Examination of radiation exposure of the population

5.3.1. Method, scope, and the initial data of the assessment

The assessment of the radiation exposure of the population was carried out by determining the expected radiation exposure of the population living within a 30 km radius of the Paks NPP in the course of the SSLE, based on the assessment of the current radiological effects and calculations carried out in accordance with the nuclear safety analyses. The magnitude of the direct and indirect radiation exposure of the population via different exposure pathways, was determined, and the radiological impact area was established based on the committed effective dose. In order

to estimate the radiation exposure, in addition to the gaseous and liquid radioactive emissions occurring under the various operational states of Paks NPP, the contributions related to artificial radiation exposures arising from other various activities and sources were also taken into account, with particular regard to the handling and transport of fresh and spent fuel assemblies and radioactive waste, the movement of radiation sources within the site, and industrial radiography examinations.

In the period of the further extension of the Paks NPP's service lifetime, Paks II NPP will also be in operation. A radiological impact assessment of the simultaneous operation of the nuclear facilities currently operating at the Paks site and those under construction at the Paks II NPP site was also carried out. As part of this, studies were conducted taking into account the operation of the Spent Fuel Interim Storage Facility (SFISF) and the Paks II NPP in addition to the operation of the four currently operating Units. The studies also included an assessment of changes in characteristics (e.g. meteorological-hydrological data or lifestyle and consumption habits typical for the local population) that may affect the radiation exposure of the population and may result in changes in terms of environmental impacts and radiation exposure of the population during the SSLE period.

The determination of the radiation exposure of the population was made taking into account the legal requirements and the authority guidelines for the performance of nuclear safety analyses. In accordance with the Hungarian practice followed also in nuclear safety analyses, the dose concepts provided in the legal provisions, mean a committed effective dose, integrated for over 50 years for adults (or up to 70 years of age in the case of children), so these values were determined in course of the investigations.

The EIARs prepared for nuclear facilities in other countries in the recent years were also processed, among others:

- the EIAR of the Loviisa NPP in Finland (Loviisa NPP, EIAR, 2021), the Environmental Impact Assessment of the Olkiluoto NPP Units 1 and 2 and uprating of their thermal power (Extending the service life of the Olkiluoto 1 and Olkiluoto 2 plant units and uprating their thermal power, Environmental impact assessment programmme, 2024),
- the EIAR of the new NPP at the Jaslovské Bohunice site in Slovakia (New NPP at the Jaslovské Bohunice site, Environmental Impact Assessment Report on the proposed activity, 2015),
- the EIAR for the planned units at the Khmelnytskyi NPP site in Ukraine (Environmental Impact Assessment Report of the planned activity, Construction of power Units 5 and 6 with AP1000 reactor units at the Khmelnytskyi NPP site, 2024).

Based on these, it was concluded that the methods used to analyse the normal operating conditions and design accidents, as well as the results and conclusions determined, are similar to the analysis tools and results used to establish Paks NPP SSLE.

5.3.2. Classification system of the radiological effects

The radiological effects of the NPP were classified based on the doses to members of the population. For this purpose, the numerical criteria used in the previous service lifetime extension and the environmental impact assessment of the Paks II NPP were applied, and the classification categories were specified accordingly. The environmental impacts caused by direct and scattered radiation and radioactive emissions (i.e. the external and internal radiation exposure to a representative person) were classified based on the classification categories provided in *Table 5.3.2-1*.

Table 5.3.2-1. Classification categories for the radiological impacts of NPPs

Classification of condition changes	Radiation exposure levels (E = committed effective dose [μSv/year])
Neutral	$E \leq 90$
Tolerable	$90 < E \leq 1{,}000$
Burdensome	$1{,}000 < E \leq 10{,}000$
Damaging	$10{,}000 < E$

The interpretation of the impact rating categories according to *Table 5.3.2-1.* is as follows:

- *Neutral*: The impact of the activity does not exceed the value determined by the authority – not significantly exceeding the lowest reasonably achievable level – i.e. the dose constraint value of 90 μSv/year.
- *Tolerable*: The upper limit of the impact of the activity is 1,000 μSv/year, which is in line with the provisions of OAH Decree 2/2022. (IV. 29.) on protection against ionizing radiation and the related licensing, reporting and monitoring system, according to which the radiation exposure of members of the public from all approved activities in a given year may not exceed the value of 1 mSv, i.e. the dose limit of 1,000 μSv.
- *Burdensome*: The upper limit of the category is an exposure effect that is considered to be the highest committed effective dose value at which protective actions are not yet required in the vicinity of the facility.
- *Damaging*: To mitigate the potential consequences of the impact of this category, protective actions must be taken outside the site, in accordance with the National Nuclear Emergency Response Plan (OBEIT).

The upper limit of the neutral effect is therefore the dose constraint value. The Hungarian National Chief Medical Officer's Office of the State Public Health and Medical Officer Service (ÁNTSZ OTH) defined in the ÁNTSZ OTH Resolution No. 40-6/1998 a dose constraint of 90 μSv/year for the Units 1-4 of the Paks NPP, as an artificial source of ionizing radiation, for members of the public. A dose constraint of 100 μSv/year was defined for the four units and the SFISF together, 90% of which applies to the Paks NPP, while 10% applies to the SFISF. The reason for dividing the dose constraint in this manner was that MVM Paksi Atomerőmű Zrt. began construction of the SFISF on its own premises as a proprietary investment. Due to changes in legislation, it was only later transferred to PURAM as a licensee independent of the power plant operator. For the two new units of Paks II NPP, a dose constraint of the same value as the dose constraint determined for the operating units was prescribed by the ÁNTSZ under file-number KEF-14831-4/2012. The value of the dose constraint is even lower than the regional fluctuations in radiation exposure from natural background radiation.

Even at a radiation exposure of 10 mSv/year, which is considered to be the upper limit of the burdensome impact, no detectable health consequences are expected. According to data published by the European Commission, the dose due to natural background radiation varies between approximately 1.5 and 6.2 mSv/year in some European countries. The value of 10 mSv corresponds approximately to the radiation exposure obtained during a whole-body CT scan. According to the National Nuclear Emergency Response Plan (OBEIT), the radiation protection of exposed persons should be optimized even in the dose range below 10 mSv, with the aim of keeping personal doses as low as reasonably achievable.

5.3.3. The investigated operational conditions and scope of the analyses

The definition of the operating conditions of a NPP and the requirements for nuclear safety analyses are set forth in OAH Decree 1/2022. (IV. 29.) on the nuclear safety requirements of nuclear facilities and related authority activities and the Nuclear Safety Code (NSC) constituting

its annexes. The categorization of the operational states of a NPP and possible events (DBC1, DBC2, DBC4, DEC1, DEC 2) is described in *Chapter 2.3.1*.

The division of the operational states in this way differs from that used in environmental legislation, which distinguishes between normal conditions and accidents. Within the framework of the radiological analyses for the SSLE the terminology used in the NSC was used. (Normal conditions correspond to operational states DBC1 and DBC2, resulting from the same criteria for doses, while the operational state DBC4 corresponds to the concept of accidents.)

The primary objective of the provisions on the extension of the design basis is to ensure that the operators of the NPP and other bodies and authorities involved in the management of emergency response were adequately prepared for the possible occurrence of events with low probability but serious consequences. Consequently, the assessment of environmental radiological impacts can be applied to normal operation and operational incidents, while the conditions considered as an extension of the design basis – primarily due to the nature of the preparation for managing their consequences – are presented in *Chapter 8* along with characterization of the impacts, within the framework of the analysis of potential impacts spreading across national borders. This is in line with the methodology applied in the environmental impact studies of the Hungarian and other European NPPs.

Section 3.2.4. of the NSC also sets out different acceptance criteria for the processes starting from the initial events leading to the individual operational states, in accordance with their different frequencies, for conditions other than normal operation. From the perspective of radiation exposure of the population, the following criteria and requirements of the NSC are relevant for the power plant environment and the public:

- ”3.2.4.0100. For processes originating from the initial event resulting in operational condition DBC2-4, it shall be proven that the dose determined per one person for the reference group of the population will not exceed:
  - for the process starting from the initial event resulting in the DBC2 operational condition the public dose constraint value, and
  - for the process starting from the initial event resulting in the DBC4 operational condition the value of 5 mSv/event.
- 3.2.4.0900. The aggregated frequency of severe accident event chains involving large or early releases, summed over for all initial operational conditions and effects – except for sabotage and earthquakes – shall not exceed the value of 10^{-5}/year, but shall be brought closer to the value of 10^{-6}/year by applying all reasonable modifications and interventions. The compliance with these requirements shall be demonstrated by level 2 probabilistic safety assessment.”

In relation to all initial events, the fulfilment of the relevant acceptance criteria shall be verified by means of safety analyses. For determination of the overall risk posed by the NPP, verification of the fulfilment of the relevant acceptance criteria, for assessing the balance and uniformity of the designs, and for assessing the adequacy of the extension of the design basis probabilistic safety assessment shall be used.

The fulfilment of the requirements is presented in the Final Safety Analysis Report (FSAR) with the content specified in the NSC, which shall be approved by the authority responsible for the supervision of nuclear safety, the Hungarian Atomic Energy Authority (HAEA). The FSAR contains the characteristics of the NPP, the description of the performed modifications, the new authority and regulatory requirements and all such information that may affect the safety analyses. The updating shall be carried out within the shortest reasonable time, as soon as new information is available and can be incorporated into the FSAR. The licensee shall annually consolidate the FSAR of the nuclear facility into a uniform structure, in accordance with changes of the nuclear facility.

In course of interpretation and comparison of the results of nuclear safety and environmental protection analyses, it should be taken into account that environmental analyses generally use the best estimate method. On the other hand, the deterministic nuclear analyses use a reasonably conservative, or the Best Estimate Plus Uncertainty (BEPU) approach. The analyses prepared as

the basis for the EIA were compiled in such a way, that their conservative, or BEPU calculation results could be compared with the corresponding criteria.

In order to assess the radiation exposure of the population, studies were conducted for the following operational states of the Paks NPP and the impact assessment was carried out using the results obtained for these:

- normal operating conditions (DBC1),
- design basis accidents (DBC4).

It should be noted that Section 3.2.4.0100 of the NSC specifies as an acceptance criterion for nuclear safety analyses of anticipated operational occurrences that, for the process originating from the initiating event leading to the DBC2 condition, it must be demonstrated that the dose to one member of the critical group (a representative person with the characteristics of the group) does not exceed the public dose constraint of 90 μSv/year, as determined under conservative assumptions. Given that the upper limit of the neutral impact is the dose constraint value and the public radiation exposure resulting from the operation of the power plant, based on the results of nuclear safety analyses of design basis accidents, remains significantly below this. The impact for the DBC2 condition falls into the neutral category in all cases. Accordingly, it was not necessary in this case to determine the impact area for state changes exceeding a neutral impact.

5.3.4. The current radiological impacts of the NPP

5.3.4.1. Public doses resulting from normal operation of the NPP

The doses to the public resulting from the normal operation of the NPP come from the release of radioactive materials (mostly internal radiation exposure) and from the direct (scattered) radiation associated with the operation (external radiation exposure). The total radiation exposure to the public resulting from the emissions of the NPP is given by the combined airborne and liquid emissions or discharges. The studies, based on both the results of the analyses so far and the results of the continuous measurements, have established that the doses resulting from the direct (scattered) radiation and from the airborne and liquid emissions are very low.

By using the most sensitive analytical methods available, the presence of artificial radionuclides in samples of environmental media, could only be detected occasionally, and even then, at low activity concentrations. In the course of the measurements carried out for the elements of the food chain, no measurement data exceeding the detection limit that could be traced back to the emissions of the NPP were observed.

Based on the sample measurement results and the data from the studies aimed at measuring the dose of additional environmental gamma radiation, it is not possible to give an accurate estimate of the amount of additional radiation exposure to the population. Since the majority of the measurements provided results below the detection limit, only an upper, very conservative estimate of the population's radiation exposure could be determined based on the detection limits.

Instead of the direct measurement data, the magnitude of the radiation exposure associated with the operation of the Paks NPP can be determined by calculation using dispersion models from the emission data, taking into account the various exposure pathways. The dose affecting the hypothetical, critical population group given by the ÁNTSZ OTH (as a conservative assumption), i.e. a representative person with the characteristics of the group, is given as the sum of the doses in village Csámpa from the gaseous emission and the doses calculated for the population in village Gerjen from the liquid discharges for children aged 1-5 years.

The total public doses in the surrounding settlements examined over 10 years (2013-2022), from gaseous emissions and liquid discharges based on the annual radiation protection reports, and the utilization of the dose constraint for the NPP site are presented in *Table 5.3.4.1-1.* The maximum public dose determined with highly conservative assumptions was 115 nSv, which represented a maximum dose constraint utilization of only 0.13%. The maximum dose for children was even lower, 110 nSv. These doses are approximately equivalent to an external effective dose caused by natural radioactivity for one hour and therefore do not pose a detectable health risk.

Table 5.3.4.1-1. Summary of external and internal radiation exposures resulting from the NPP's gaseous emissions and liquid discharges for 2013-2022 and data on the utilization of the dose constraint

Year	From Csámpa gaseous emissions + Gerjen liquid discharges		Utilization of the dose constraint [%]
	Adult [nSv]	Child [nSv]	
2013	$5.14 \cdot 10^{1}$	$4.83 \cdot 10^{1}$	0.054
2014	$6.30 \cdot 10^{1}$	$5.99 \cdot 10^{1}$	0.067
2015	$9.23 \cdot 10^{1}$	$8.77 \cdot 10^{1}$	0.097
2016	$7.50 \cdot 10^{1}$	$6.96 \cdot 10^{1}$	0.077
2017	$9.16 \cdot 10^{1}$	$8.58 \cdot 10^{1}$	0.095
2018	$1.04 \cdot 10^{2}$	$9.65 \cdot 10^{1}$	0.107
2019	$6.73 \cdot 10^{1}$	$6.11 \cdot 10^{1}$	0.068
2020	$7.21 \cdot 10^{1}$	$6.49 \cdot 10^{1}$	0.072
2021	$8.80 \cdot 10^{1}$	$8.11 \cdot 10^{1}$	0.090
2022	$1.15 \cdot 10^{2}$	$1.10 \cdot 10^{2}$	0.122
Minimum	$5.14 \cdot 10^{1}$	$4.83 \cdot 10^{1}$	0.054
Maximum	$1.15 \cdot 10^{2}$	$1.10 \cdot 10^{2}$	0.122
Average	$8.19 \cdot 10^{1}$	$7.65 \cdot 10^{1}$	0.085
Standard deviation	$1.96 \cdot 10^{1}$	$1.90 \cdot 10^{1}$	0.021

Based on the data presented above, it was determined that the excess radiation exposure to the population in the course of normal operation of the Paks NPP to the present, has not had any detectable health effects. The environmental effects caused by the normal operational radioactive emissions and discharges of the NPP can be classified as neutral.

During the period of the extended service lifetime of the NPP, no change in the magnitude of the gaseous and liquid radioactive emissions and discharges – and consequently any significant increase in the radiation exposure of the population – is anticipated compared to the past. It will be possible to determine the consequences of the actual emissions and discharges based on the measurement data of the monitoring system and the results of model calculations.

The direct (scattered) radiation exposure to members of the population living in the vicinity of the site can occur from several sources, of which the following can be highlighted in terms of radiological effects related to the operation of the Paks NPP:

- transportation of fresh fuel to the site,
- transportation of spent fuel to the adjacent interim storage facility, the SFISF,
- transportation of radioactive waste from the site,
- movement of devices and radiation sources containing radionuclides on their surfaces within the site area,
- use of high-activity radiation sources for various radiographic examinations during industrial radiography examinations, including their transportation to and from the site, if they are not stored on the site.

In course of the stand-alone operation of the Paks NPP, the direct radiation exposure from the above listed activities is very low, as is confirmed by the calculations performed for the new NPP units in relation to site of Paks NPP. Due to the uncertainties, the calculations were performed with highly conservative assumptions. The highest values may come from the transportation of radioactive waste and from the use of high-activity radiation sources used during industrial radiography examinations. In relation to these it is also true that even under the most conservative assumptions, the radiation exposure of a representative person does not exceed the value of a few μSv/year. The annual radiation exposure of the population attributable to the transportation of fresh fuel is below 1 μSv, while the radiation exposure from the transportation of the spent fuel

to the SFISF and from the movement of devices and radiation sources containing radionuclides on their surfaces on the site area is several orders of magnitude lower, below 1 nSv. The direct radiation exposure of the population from the stand-alone operation of the Paks NPP does not reach the value of 90 μSv/year even despite very conservative scenarios and is classified as neutral based on the radiological impact classification system.

5.3.4.2. Radioactive emissions from NPP accidents

For characterization of the possible radiation exposure, in course of operation of the Paks NPP environmental radiological effects that differ from normal operation the events that occurred during the operation, so far might be taken into consideration, involving such emissions of radioactive materials, which was exceeding the usual level of normal operational emissions. In the course of operation of the NPP so far, there were only a few incidents involving operational emissions, as a result of which appearance of radioactive materials in the environment (in the case of liquid emissions, tritium, fission and activation products, in the case of gaseous emissions, radioactive noble gases, iodine isotopes in elemental, organic and aerosol forms and other fission products) could also be detected.

In the case of the Paks NPP's emergency radioactive releases, the detection of the activity in the environment demonstrated the very high sensitivity of nuclear measurement technology, by means of which it has been confirmed, that the releases did not have any environmental or health consequences. This is supported by the fact that after the accidental releases – following a possible short-term increase in levels – the activity concentrations measured in water and food samples were in all cases by orders of magnitude below the permissible activity concentrations, and the dose rate of the environmental radiation remained at the level of normal, natural background radiation. The highest soil surface contamination of the isotopes with a considerable proportion falling out of the radioactive plume was also very low, the dose rate calculated from this did not reach the value of 1 nSv/h, which is approximately 1% of the natural background radiation and falls far within the range of fluctuations in the natural radiation level. The effective dose calculated from the inhalation and ingestion of radionuclides was in the order of nSv, which is an extremely small value, corresponding to the radiation exposure from natural background radiation in approximately 1 minute.

5.3.5. Changes anticipated due to Paks NPP SSLE

The impacts anticipated from the operation of the Paks NPP during the further extension of its service lifetime were first assessed based on the results of previous analyses, separately for the stand-alone operation of the power plant, and then for the combined operation of the Paks NPP and Paks II NPP, taking into account the potential radiological effects of design basis accidents. Subsequently, new dose calculations in relation to the extension of services lifetime of the Paks NPP, were presented, the results of which were evaluated in comparison with the operation of Paks II NPP. Such an approach ensures the full-scope consideration of existing information, the placing of new results in the appropriate context, and a comprehensive assessment of the impact of the entire system in terms of population radiation exposure.

5.3.5.1. Assessment of expected public radiation exposure during the period of further operation based on previous analyses

5.3.5.1.1. Radiological impacts of the stand-alone operation of the Paks NPP

In the course of the assessment of the radiological impacts, direct and indirect impacts can be distinguished. Based on previous measurements and calculations, the direct radiation exposure of the population from the stand-alone operation of the Paks NPP does not reach the value of 90 μSv/year, despite very conservative scenarios and assumptions. Due to the typical similarity of the activities and the resulting direct impacts, no change in the direct impacts is anticipated in course of operation during the extended service life of the NPP compared to the current operation.

The impact of direct (scattered) radiation related to the operation of the Paks NPP is negligible. Based on this, the operation of the power plant is neutral according to the radiological impact classification system.

The indirect effects include external and internal doses from the gaseous and liquid emissions of the NPP. Based on the review of previous results regarding the indirect effects of the stand-alone operation of the Paks NPP, it can be concluded that no significant change in the radiation exposure of the population is expected in the course the further extension of the operational period. The radiological impact area of normal operation of the NPP with an extended operational period will not change substantially, compared to the current impact area, it will continue to remain within the operational area.

5.3.5.1.2. Radiological impacts of the simultaneous operation of the Paks NPP and the Paks II NPP

The Paks II NPP EIAR also includes statements regarding the radiological impact of simultaneous operation of the Paks NPP, the SFISF and the Paks II NPP. In order to be able to estimate the combined radiological impact, the radiation exposures from normal operation were aggregated. Using the aggregated available data of the three facilities (Paks NPP, SFISF and Paks II NPP), the maximum total doses determined for the years examined there (2001-2012) are given in *Tables 5.3.5.1.2-1.* and *5.3.1.2-2.* for two age groups (children 1-2 years old and adults) and for Csámpa and for locations at different distances from the discharge point (<5 km, 5-10 km, 10-30 km). In *Table 5.3.1.2-3.* the maximum combined impact of liquid discharges in Gerjen is presented. These analyses were made using the same methodology as the calculations presented in *Chapter 5.3.4.1*. However, emissions and meteorological data for different years were used, which explains the differences between the doses for the Paks NPP. However, it is important to emphasize that the determined dose values are low in both cases and the conclusions regarding their effects are the same.

Based on the presented data, it can be seen that the total dose determined for normal operational emissions does not reach the value of 1 μSv, i.e. it remains by two orders of magnitude below, the upper value of the neutral range of the radiological impact classification system.

Table 5.3.5.1.2-1. The maximum values of total doses from Paks NPP, SFISF and Paks II NPP for children aged 1-2 years [nSv]

Plant / territory	Csámpa	<5 km	5-10 km	10-30 km
Paks NPP	$8.40 \cdot 10^{1}$	$4.00 \cdot 10^{1}$	$6.50 \cdot 10^{0}$	$1.00 \cdot 10^{0}$
SFISF	$1.40 \cdot 10^{0}$	$4.00 \cdot 10^{-1}$	$6.60 \cdot 10^{-2}$	$1.00 \cdot 10^{-2}$
Paks II NPP	$6.90 \cdot 10^{1}$	$3.90 \cdot 10^{1}$	$9.00 \cdot 10^{0}$	$1.50 \cdot 10^{0}$
In total	$1.54 \cdot 10^{2}$	$7.94 \cdot 10^{1}$	$1.56 \cdot 10^{1}$	$2.51 \cdot 10^{0}$

Table 5.3.5.1.2-2. The maximum values of total doses from Paks NPP, SFISF and Paks II NPP for adults [nSv]

Plant / territory	Csámpa	<5km	5-10 km	10-30 km
Paks NPP	$6.00 \cdot 10^{1}$	$2.90 \cdot 10^{1}$	$4.70 \cdot 10^{0}$	$7.30 \cdot 10^{-1}$
SFISF	$7.00 \cdot 10^{-1}$	$2.10 \cdot 10^{-1}$	$3.40 \cdot 10^{-2}$	$6.60 \cdot 10^{-3}$
Paks II NPP	$5.90 \cdot 10^{1}$	$3.30 \cdot 10^{1}$	$7.50 \cdot 10^{0}$	$1.30 \cdot 10^{0}$
In total	$1.20 \cdot 10^{2}$	$6.22 \cdot 10^{1}$	$1.22 \cdot 10^{1}$	$2.04 \cdot 10^{0}$

Table 5.3.5.1.2-1: The maximum values of combined impact of liquid emissions in Gerjen on an annual basis [nSv]

Children aged 1-2 years	Adult
$1.54 \cdot 10^{2}$	$2.04 \cdot 10^{2}$

Regarding the direct impacts, based on the results of the analyses described in the EIAR of Paks II NPP, the effect does not exceed the public dose constraint value even within 500 m.

In the case of the SFISF, in addition to the radiological effect of normal operational emissions, the population radiation exposure resulting from direct and scattered radiation cannot be neglected. In this regard, based on the calculations performed for the new NPP units at the Paks NPP site and the calculations described in the document presenting the determination of dose rates outside the SFISF site, the external radiation exposure to the population of Csámpa from the handling and storage of spent fuel assemblies at the time when the 33 vaults of the SFISF will be fully loaded, will not exceed a few μSv/year. This negligible effect will not be significantly modified by the additional dose contribution resulting from the planned storage of spent fuel assemblies generated during the period of the extended operational lifetime period in the Holtec UMAX storage system.

Based on the review of previous results regarding the radiological effects of the combined operation of Paks NPP, Paks II NPP and the SFISF, it can be stated in the case of both direct and indirect effects that the combined impact area will not exceed the upper value of the neutral impact of 90 μSv/year at the border of the safety zone(s) (500 m).

5.3.5.1.3. Radiological effects of accidents

One of the tasks of the nuclear safety analyses for the Paks NPP (including analyses of design basis accidents) is to determine the amount of radioactive release and radiation exposure to individuals in the event of various accidents. In the course of the analyses, the amount of radioactive material released into the atmosphere and the environmental doses that can be compared with the criteria were determined for accidents in case of which, the integrity of the primary circuit and/or part of the fuel rods are damaged.

The assessment covered a number of initial events included in the design basis of the NPP, and the studies were carried out for the cases given in *Table 5.3.5.1.3-1*. Atmospheric releases to the environment can be classified into four possible groups from the point of view of the release pathway:

- through the containment into the reactor hall and the surrounding rooms, then through the 120 m high ventilation stack into the environment due to the operational ventilation (cases 1-10 and PR-1),
- by bypassing the containment, through the broken safety valve of the steam generator, or through the atmospheric discharge valve, into the environment at a height of 44 m in the release pipe (case PR-2),
- from the shut-down, open reactor into the reactor hall, then through the operating ventilation into the environment (cases NYR-1 and NYR-2),
- from the spent fuel pool into the reactor hall, then through the operational ventilation into the environment (cases PM-1, PM-2, PM-3 and PM-4).

The environmental dose calculations for the accident cases were made using meteorological and population parameters typical for the Paks NPP area, located at a receptor point (Csámpa) 1 km from the power plant. The dose calculations were based on the 2-day and 7-day effective doses, as well as the 50-year effective doses, of the reference group of the population, i.e. a representative person with the characteristics of the group, for the different accident cases.

Based on the analysis results, it can be stated that in the case of design base failures (processes starting from the initial event resulting in DBC4 operating conditions), the dose of the reference group of the population, i.e. the representative person, will not exceed the value of 5 mSv/event. Interpreting the criterion as a committed effective dose, it can be stated that the criterion is met with great certainty even in the case of the conservative assumptions used. In the case of other initial events analysed as the design basis of the NPP, it was unambiguous that the public doses in case of them would be far below the values according to the criteria prescribed in the law. Based on the performed analyses, it can be stated that, as a result of the thermohydraulic processes and processes taking place in the containment, and especially the time course of the

events, the highest committed effective dose values would occur when the DN 90 mm pipeline breaks (case 3), or when the DN 492 mm hot-leg pipeline breaks (case 9).

Table 5.3.5.1.3-1. The investigated design basis accident (DBC4) cases

Serial number	Name of the accident
Emission through the containment	
1.	Break of the DN 73 mm line of the water purifier No. 1 in loop 5 at 1485 MW thermal power, assuming loss of off-site power
2.	Break of the DN 90 mm connecting pipe between the pressurizer and the safety valve at a thermal power of 1485 MW, assuming loss of off-site power
3.	Break of the DN 90 mm pressurizer injection pipe at 1485 MW thermal power, assuming loss of off-site power
4.	Break of DN 111 mm high-pressure ECCS line in loop 5 at 1485 MW thermal power, assuming loss of off-site power
5.	Break of the DN 233 mm low-pressure ECCS line in loop 4 at 1485 MW thermal power, assuming loss of off-site power
6.	Break of the DN 277 mm surge line of the pressurizer at 1485 MW thermal power, assuming loss of off-site power
7.	Break of the DN 492 mm cold-leg pipe in loop 4 at 1485 MW thermal power, assuming loss of off-site power and using maximum ECCS configuration
8.	Break of the DN 492 mm cold-leg pipe break in loop 4 at 1485 MW thermal power, assuming loss of off-site power. The containment isolation valves of the TN and UH ventilation systems close with a 5 s delay
9.	Break of the DN 492 mm hot-leg in loop 4 at 1485 MW thermal power, with 2 containment spray systems operating
10.	ATWS following unintentional pulling out of a control rod
PR-1	PRISE with secondary side blow-off (the part through the containment)
Emission by bypassing the containment	
PR-2	PRISE with secondary side blow-off (the part bypassing the containment)
Emission from the shut-down, opened reactor	
NYR-1	Dropping of a fuel assembly
NYR-2	Disturbance of the natural circulation
Emission from the spent fuel pool	
PM-1	Dropping of a fuel assembly
PM-2	Loss of cooling starting from the refuelling water level
PM-3	Loss of cooling starting from normal water level
PM-4	Loss of coolant starting from the refuelling water level

In the EIAR prepared in 2006, for the first service lifetime extension of the Paks NPP, it was stated that the tolerable effects in the case of design basis accidents are probable up to a distance of 6.3 km from the emission point, and beyond that, only neutral effects should be anticipated. The safety analyses and the investigations carried out in course of preparation of the EIAR for the first service lifetime extension also established that the impact of liquid release from accidents is by several orders of magnitude lower than the consequences of gaseous emissions presented earlier.

5.3.5.2. Assessment of anticipated radiation exposure of the public in course of the SSLE of the NPP based on new analyses

5.3.5.2.1. Method and initial data of the investigation

In order to assess the anticipated radiation exposure of the population living within a 30 km radius of the site in the course of the further extension of the NPP's service lifetime, the radiological effects that occurred during the operation of the NPP so far (*Chapter 5.3.4.*) and the results of previously conducted analyses (*Chapter 5.3.5.1.*) were taken into account.

New analyses were also prepared to determine the radiation exposure of the population and the radiological impact area, taking into account the latest available data. Furthermore, an assessment was made of the changes related to modification of the characteristics that might change in the course of the SSLE (e.g. meteorological-hydrological data or lifestyle and consumption habits typical of the local population) that influence the radiation exposure of the population may result in from the point of view of environmental impacts.

In accordance with the determination, of which operational states of Paks NPP should be analysed (*Chapter 5.3.3.)*, the environmental radiological impacts associated with the further operation of the power plant were assessed based on the gaseous and liquid emissions during normal operation, as well as the potential gaseous emissions of design basis accidents.

In order to determine the radiation conditions emerging in the environment and the public doses, the applicable analytical tool, the emission source term and the conditions of the emission to be taken into account, the applicable input data in terms of meteorological and hydrological conditions, and in relation to the population's lifestyle and consumption habits were determined for each operational state to be examined. Furthermore, the exposure pathways to be taken into account, the receptor points located at different distances and directions, for which specific dose values form the basis for the findings regarding the radiological impact area, were determined.

It should be noted that design basis accidents include leakage or failure of the liquid radioactive waste system and the presumed emissions from the storages for the liquids. In these cases, the leakage occurs in a room of the power plant, from where gaseous radioactive material may be released into the environment by evaporation and through the ventilation systems (the activity of which is several orders of magnitude lower than the atmospheric releases examined in this context), i.e. no liquid emissions to the River Danube may occur in these cases. In the case of design basis accidents, the aquatic dispersion analyses were made assuming fallout of the gaseous emissions into the River Danube.

5.3.5.2.2. Radiological impacts of the stand-alone operation of Paks NPP

Normal operational condition (DBC1)

The doses determined for the normal operation based on the actual gaseous discharge data for 2022 for 1-year-old children and adults are summarized in *Table 5.3.5.2.2-1.*, for the investigated 16 directional sectors and at different distances. In Csámpa, at a distance of approx. 1 km from the NPP, in the direction of the 12th sector, the calculated effective dose of a representative adult is 3.64 nSv for adults, while for children it is 1.63 nSv. The doses from each of exposure pathways that were taken into consideration are summarized in the results.

It can be seen from the results, that in all cases, after the emitted radioactive plume reaches the ground (which in these calculation occur within 500 m from the discharge point), the doses decrease with increasing the distance from the power plant. Beyond the examined distances, there is no such process or effect, moving farther away from the discharge point that could cause the activity concentrations obtained by atmospheric dispersion modelling and the dose calculation results derived from it to increase again.

Table 5.3.5.2.2-1. Committed effective doses determined based on actual gaseous discharge data for 2022 for the normal operating condition (DBC1), for representative adult and 1-year-old child, in 16 directional sectors

Receptor point, Distance from release point [km]		Committed effective dose [nSv]		Receptor point, Distance from release point [km]		Committed effective dose [nSv]	
		Adult	1-year-old child			Adult	1-year-old child
Sector 1 (N)	0.5	$5.42 \cdot 10^{0}$	$2.42 \cdot 10^{0}$	9th sector (South direction)	0.5	$8.01 \cdot 10^{0}$	$3.50 \cdot 10^{0}$
	1.0	$3.63 \cdot 10^{0}$	$1.77 \cdot 10^{0}$		1.0	$4.42 \cdot 10^{0}$	$2.08 \cdot 10^{0}$
	3.0	$1.28 \cdot 10^{0}$	$6.52 \cdot 10^{-1}$		3.0	$9.92 \cdot 10^{-1}$	$5.05 \cdot 10^{-1}$
	5.0	$6.96 \cdot 10^{-1}$	$3.53 \cdot 10^{-1}$		5.0	$4.87 \cdot 10^{-1}$	$2.51 \cdot 10^{-1}$
	10	$3.07 \cdot 10^{-1}$	$1.56 \cdot 10^{-1}$		10	$2.15 \cdot 10^{-1}$	$1.12 \cdot 10^{-1}$
	30	$9.89 \cdot 10^{-2}$	$5.16 \cdot 10^{-2}$		30	$7.52 \cdot 10^{-2}$	$3.95 \cdot 10^{-2}$
2nd sector (North, North-East direction)	0.5	$5.28 \cdot 10^{0}$	$2.33 \cdot 10^{0}$	10th sector (South, South-West direction)	0.5	$8.28 \cdot 10^{0}$	$3.57 \cdot 10^{0}$
	1.0	$2.82 \cdot 10^{0}$	$1.37 \cdot 10^{0}$		1.0	$4.10 \cdot 10^{0}$	$1.86 \cdot 10^{0}$
	3.0	$8.82 \cdot 10^{-1}$	$4.52 \cdot 10^{-1}$		3.0	$9.07 \cdot 10^{-1}$	$4.28 \cdot 10^{-1}$
	5.0	$4.75 \cdot 10^{-1}$	$2.43 \cdot 10^{-1}$		5.0	$4.02 \cdot 10^{-1}$	$1.93 \cdot 10^{-1}$
	10	$2.13 \cdot 10^{-1}$	$1.09 \cdot 10^{-1}$		10	$1.38 \cdot 10^{-1}$	$6.92 \cdot 10^{-2}$
	30	$7.00 \cdot 10^{-2}$	$3.63 \cdot 10^{-2}$		30	$4.19 \cdot 10^{-2}$	$2.18 \cdot 10^{-2}$
3rd sector (North-East direction)	0.5	$7.06 \cdot 10^{0}$	$3.08 \cdot 10^{0}$	11th sector (South-West direction)	0.5	**$1.22 \cdot 10^{1}$**	**$5.16 \cdot 10^{0}$**
	1.0	$3.25 \cdot 10^{0}$	$1.52 \cdot 10^{0}$		1.0	$5.06 \cdot 10^{0}$	$2.22 \cdot 10^{0}$
	3.0	$8.72 \cdot 10^{-1}$	$4.28 \cdot 10^{-1}$		3.0	$8.14 \cdot 10^{-1}$	$3.82 \cdot 10^{-1}$
	5.0	$4.72 \cdot 10^{-1}$	$2.30 \cdot 10^{-1}$		5.0	$3.14 \cdot 10^{-1}$	$1.52 \cdot 10^{-1}$
	10	$2.06 \cdot 10^{-1}$	$1.01 \cdot 10^{-1}$		10	$9.35 \cdot 10^{-2}$	$4.85 \cdot 10^{-2}$
	30	$5.73 \cdot 10^{-2}$	$2.92 \cdot 10^{-2}$		30	$3.13 \cdot 10^{-2}$	$1.65 \cdot 10^{-2}$
4th sector (North-East, East direction)	0.5	$5.95 \cdot 10^{0}$	$2.62 \cdot 10^{0}$	12th sector (South-West, West direction)	0.5	$9.25 \cdot 10^{0}$	$3.94 \cdot 10^{0}$
	1.0	$2.74 \cdot 10^{0}$	$1.30 \cdot 10^{0}$		1.0	$3.64 \cdot 10^{0}$	$1.63 \cdot 10^{0}$
	3.0	$6.56 \cdot 10^{-1}$	$3.29 \cdot 10^{-1}$		3.0	$6.08 \cdot 10^{-1}$	$2.92 \cdot 10^{-1}$
	5.0	$3.32 \cdot 10^{-1}$	$1.67 \cdot 10^{-1}$		5.0	$2.77 \cdot 10^{-1}$	$1.35 \cdot 10^{-1}$
	10	$1.40 \cdot 10^{-1}$	$7.10 \cdot 10^{-2}$		10	$1.07 \cdot 10^{-1}$	$5.32 \cdot 10^{-2}$
	30	$4.52 \cdot 10^{-2}$	$2.32 \cdot 10^{-2}$		30	$3.09 \cdot 10^{-2}$	$1.60 \cdot 10^{-2}$
5th sector (East direction)	0.5	$5.62 \cdot 10^{0}$	$2.48 \cdot 10^{0}$	13th sector (West direction)	0.5	$6.75 \cdot 10^{0}$	$2.90 \cdot 10^{0}$
	1.0	$2.64 \cdot 10^{0}$	$1.26 \cdot 10^{0}$		1.0	$2.93 \cdot 10^{0}$	$1.34 \cdot 10^{0}$
	3.0	$6.54 \cdot 10^{-1}$	$3.32 \cdot 10^{-1}$		3.0	$8.19 \cdot 10^{-1}$	$3.91 \cdot 10^{-1}$
	5.0	$3.36 \cdot 10^{-1}$	$1.69 \cdot 10^{-1}$		5.0	$4.34 \cdot 10^{-1}$	$2.06 \cdot 10^{0}$
	10	$1.44 \cdot 10^{-1}$	$7.31 \cdot 10^{-2}$		10	$1.74 \cdot 10^{-1}$	$8.34 \cdot 10^{-2}$
	30	$4.45 \cdot 10^{-2}$	$2.31 \cdot 10^{-2}$		30	$4.02 \cdot 10^{-2}$	$2.08 \cdot 10^{-2}$
6th sector (East, South-East direction)	0.5	$4.26 \cdot 10^{0}$	$1.92 \cdot 10^{0}$	14th sector (West, North-West direction)	0.5	$5.75 \cdot 10^{0}$	$2.51 \cdot 10^{0}$
	1.0	$2.55 \cdot 10^{0}$	$1.22 \cdot 10^{0}$		1.0	$2.71 \cdot 10^{0}$	$1.25 \cdot 10^{0}$
	3.0	$7.11 \cdot 10^{-1}$	$3.50 \cdot 10^{-1}$		3.0	$5.90 \cdot 10^{-1}$	$3.00 \cdot 10^{-1}$
	5.0	$3.28 \cdot 10^{-1}$	$1.63 \cdot 10^{-1}$		5.0	$3.12 \cdot 10^{-1}$	$1.58 \cdot 10^{-1}$
	10	$1.17 \cdot 10^{-1}$	$6.07 \cdot 10^{-2}$		10	$1.35 \cdot 10^{-1}$	$6.89 \cdot 10^{-2}$
	30	$4.13 \cdot 10^{-2}$	$2.16 \cdot 10^{-2}$		30	$4.45 \cdot 10^{-2}$	$2.31 \cdot 10^{-2}$
7th sector (South-East direction)	0.5	$7.39 \cdot 10^{0}$	$3.21 \cdot 10^{0}$	15th sector (North-West direction)	0.5	$6.41 \cdot 10^{0}$	$2.86 \cdot 10^{0}$
	1.0	$3.74 \cdot 10^{0}$	$1.71 \cdot 10^{0}$		1.0	$3.31 \cdot 10^{0}$	$1.54 \cdot 10^{0}$
	3.0	$7.95 \cdot 10^{-1}$	$3.89 \cdot 10^{-1}$		3.0	$8.12 \cdot 10^{-1}$	$4.04 \cdot 10^{-1}$
	5.0	$3.69 \cdot 10^{-1}$	$1.83 \cdot 10^{-1}$		5.0	$4.25 \cdot 10^{-1}$	$2.13 \cdot 10^{-1}$
	10	$1.39 \cdot 10^{-1}$	$7.09 \cdot 10^{-2}$		10	$1.81 \cdot 10^{-1}$	$9.14 \cdot 10^{-2}$
	30	$4.37 \cdot 10^{-2}$	$2.30 \cdot 10^{-2}$		30	$5.61 \cdot 10^{-2}$	$2.91 \cdot 10^{-2}$

Receptor point, Distance from release point [km]		Committed effective dose [nSv]		Receptor point, Distance from release point [km]		Committed effective dose [nSv]	
		Adult	1-year-old child			Adult	1-year-old child
8th sector (South-East, South direction)	0.5	$7.05 \cdot 10^{0}$	$3.08 \cdot 10^{0}$	16th sector (North-West, North direction)	0.5	$5.69 \cdot 10^{0}$	$2.60 \cdot 10^{0}$
	1.0	$3.83 \cdot 10^{0}$	$1.78 \cdot 10^{0}$		1.0	$3.36 \cdot 10^{0}$	$1.62 \cdot 10^{0}$
	3.0	$9.07 \cdot 10^{-1}$	$4.46 \cdot 10^{-1}$		3.0	$1.04 \cdot 10^{0}$	$5.29 \cdot 10^{-1}$
	5.0	$4.53 \cdot 10^{-1}$	$2.24 \cdot 10^{-1}$		5.0	$5.66 \cdot 10^{-1}$	$2.87 \cdot 10^{-1}$
	10	$1.80 \cdot 10^{-1}$	$9.08 \cdot 10^{-2}$		10	$2.57 \cdot 10^{-1}$	$1.30 \cdot 10^{-1}$
	30	$5.64 \cdot 10^{-2}$	$2.94 \cdot 10^{-2}$		30	$8.51 \cdot 10^{-2}$	$4.37 \cdot 10^{-2}$

The maximum dose values for each representative individual person are indicated in bold and italics in the table.

Concerning the dose consequences of normal operational gaseous discharges to the population, it can be stated, that it falls into the neutral category everywhere in the vicinity of the NPP, and it is significantly below the dose constraint of 90 μSv/year and the upper limit of the neutral effect.

The maximum of the calculated committed effective dose values, the 12.2 nSv value determined for adults at a distance of 500 m in the direction of the 11th sector (South-West direction), is less than 0.02% of the dose constraint value. Thus, the results of our analyses for determining the radiation exposure of the population are therefore consistent and in the same order of magnitude as the results of the analyses carried out by MVM Paksi Atomerőmű Zrt. for determination of the public doses from gaseous radioactive emissions, included in their annual radiation protection report.

The range of the dose results from the analyses was at a distance of 1 km in different sectors for adults 2.55-5.06 nSv, and for 1-year-old children it was 1.22-2.22 nSv, while the doses determined for Csámpa, based on the 2013-2022 airborne radioactive emissions of the NPP by the annual radiation protection reports, were between 5.12 nSv and 50.4 nSv for adults, and between 5.02 nSv and 49.4 nSv for children.

Although the analyses performed for determination of the radiation exposure of the population were carried out taking into account the same source term as the analyses included in the annual radiation protection report (the activity concentration of the actual gaseous discharges of the NPP determined by measurements), they are different, due to changes in other input data taken into account in the calculations (model parameters, lifestyle-consumption characteristics) and the continuous development of the methodology and tools of the analyses.

Thus, based on the analyses, the radiological impact area of the normal operation gaseous discharges, remain within the safety zone boundary (500 m), and the population radiation exposure, can be estimated at a value significantly below the dose constraint of 90 μSv/year and the upper limit of the neutral effect.

The analysis performed for determination of the consequences of liquid discharges was made using the actual liquid emission data of the NPP during normal operation in 2021, assuming the release to be continuous and originating from a point source along the coast.

The calculated values of the committed effective dose of representative persons in Gerjen, at a distance of 10 km from the NPP are presented in *Table 5.3.5.2.2-2*. The dose from the actual liquid discharge of the NPP during normal operation in 2021 was dominated by the contribution of ^{14}C, accounting for more than 90% of the total dose for both an adult and a 1-year-old representative person. The total dose was dominated by internal radiation exposure from fish consumption, with the internal and total doses of adults being higher than those of children due to different consumption values.

The results of the calculations performed for examination of the distance dependence of doses due to normal operational liquid discharges are presented in *Table 5.3.5.2.2-3*.

There are no inhabited settlements in the immediate vicinity of the release point, so the doses received at the nearby receptor points (especially those recorded at 0.5 km) are not to be evaluated in relation to the radiation exposure of the population, although even here, they remain several orders of magnitude below the dose constraint of 90 μSv/year and the upper limit of the

neutral effect. Based on the distance dependence it can be established that as the pollutant mixes more and more in the transverse direction as it moves away from the emission point, and its activity decreases as a result of radioactive decay, the river-bank dose values for both age groups became lower and lower as it moves farther away from the emission point. Outside the range examined in course of the analyses, at greater distances, no process or effect is anticipated that would cause an increase in the results of the aquatic dispersion modelling and the dose calculation derived from it.

Table 5.3.5.2.2-2. Committed effective doses determined for the normal operating condition (DBC1) based on actual liquid emissions data for 2021, for representative adults and children, from different exposure routes

Radiation exposure pathway	Committed effective dose [nSv]	
	Adult	1-year-old children
Total	$3.53 \cdot 10^{1}$	$3.18 \cdot 10^{1}$
Swimming – external skin dose from beta radiation	$5.90 \cdot 10^{-5}$	
Swimming – external gamma radiation dose	$5.04 \cdot 10^{-5}$	
Water related activities – external gamma radiation dose	$1.04 \cdot 10^{-1}$	
Fish consumption – internal dose	$3.52 \cdot 10^{1}$	$3.17 \cdot 10^{1}$

Table 5.3.5.2.2-3. The distance dependence of committed effective doses determined based on actual liquid discharge data for 2021 for the normal operating condition (DBC1)

The distance from emission point [km], Receptor point	Committed effective dose [nSv]	
	Adult	1-year-old children
0.50	$1.57 \cdot 10^{2}$	$1.41 \cdot 10^{2}$
1.0	$1.11 \cdot 10^{2}$	$1.00 \cdot 10^{2}$
3.0	$6.43 \cdot 10^{1}$	$5.78 \cdot 10^{1}$
5.0	$4.98 \cdot 10^{1}$	$4.48 \cdot 10^{1}$
10, Gerjen	**$3.53 \cdot 10^{1}$**	**$3.18 \cdot 10^{1}$**
30	$2.03 \cdot 10^{1}$	$1.83 \cdot 10^{1}$

Concerning dose consequences of normal operational liquid discharge to the population, it can be stated that they are in the neutral category everywhere, in the vicinity of the NPP, with values several orders of magnitude below the dose constraint (90 μSv/year). The maximum value of the calculated committed effective doses – 157 nSv determined 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 in case of Gerjen is 35.3 nSv for adults and 31.8 nSv for 1-year-old children, while the doses determined according to the annual radiation protection reports based on the liquid radioactive discharges of the NPP for 2013-2022, are between 36.8 nSv and 82.2 nSv for adults and between 33.8 nSv and 75.2 nSv for children. The results of the analyses performed for determination of the radiation exposure of the population are in the same order of magnitude as the results of the analyses performed by the power plant to determine the doses to the population from liquid radioactive emissions, included in the annual radiation protection report.

The applied source term (the activity concentration of the actual liquid emissions of the NPP determined by measurements) and other input data taken into account in the calculations (model parameters, hydrological, lifestyle and consumption characteristics) were identical to the analyses of MVM Paksi Atomerőmű Zrt. However, the continuously developing methodology and tools of the analyses, as well as the degree of conservatism of the assumptions and considerations, differ.

Such a degree of differences between the data obtained in the analyses performed for determination of the normal operational public radiation exposure and the data provided as a result of previous analyses is acceptable, and based on these, it can be stated that despite the differences in the methodology and the data used, the conclusions regarding public radiation exposure, radiological effects and impact area are the same.

Design basis accident (DBC4)

Concerning the design basis accidents, calculations were made for the cases listed in *Table 5.3.5.1.3-1*. The value of the public doses due to the gaseous emissions at receptor points within a distance of 30 km was the highest in the 3rd emission case (break of the DN 90 mm pressurizer injection line at a thermal power of 1485 MW, assuming a complete blackout), so these results are presented.

The doses determined for the 3rd design basis accident release case are summarized in *Table 5.3.5.2.2-4.* for representative 1-year-old children and adults in the 16 directional sectors examined and at different distances. In Csámpa, at a distance of approx. 1 km from the NPP, the calculated effective dose of a representative adult is 425 μSv, while that of a 1-year-old child is 349 μSv.

Based on the results it can be seen that after the radioactive plume reaches the ground, the doses decrease in line with increasing distance from the power plant. Beyond the investigated distances, there is no such process or effect moving farther away from the release point that could increase the results of atmospheric propagation modelling and the resulting dose calculation. The aim of the analyses was not the calculation of the maximum dose value, but the determination of the distances where the dose drops below a given limit value.

Based on the analyses, it can be stated that the public dose consequences examined in the case of the DBC4 design basis accident will not exceed the upper limit of tolerable effects, i.e. 1 mSv. The tolerable effects (≤1 mSv) might be observed up to approx. 5-6 km from the release point, and neutral effects (≤90 μSv) might be observed beyond that due to the gaseous emissions associated with the design basis accidents.

For the 3rd design basis accident case (*Table 5.3.5.1.3-1.*), the radiological impact area for 1-year-old children and adults with a dose value exceeding 90 μSv from gaseous discharges was determined, which is presented in the diagrams of *Figure 5.3.5.2.2-1*. The boundary of the impact area was determined with an accuracy of 100 m in the different direction sectors.

Table 5.3.5.2.2-3. Committed effective doses determined for the 3rd design basis accident (DBC4) emission case for representative adults and 1-year-old children, in 16 direction sectors

Receptor point, Distance from emission point [km]		Committed effective dose [μSv]		Receptor point, Distance from emission point [km]		Committed effective dose [μSv]	
		Adult	1-year-old children			Adult	1-year-old children
1st sector (North direction)	0.5	$3.24 \cdot 10^{2}$	$2.52 \cdot 10^{2}$	9th sector (South direction)	0.5	$3.26 \cdot 10^{2}$	$2.71 \cdot 10^{2}$
	1.0	$4.17 \cdot 10^{2}$	$3.37 \cdot 10^{2}$		1.0	$4.20 \cdot 10^{2}$	$3.52 \cdot 10^{2}$
	3.0	$1.64 \cdot 10^{2}$	$1.30 \cdot 10^{2}$		3.0	$1.53 \cdot 10^{2}$	$1.26 \cdot 10^{2}$
	5.0	$8.74 \cdot 10^{1}$	$6.78 \cdot 10^{1}$		5.0	$7.94 \cdot 10^{1}$	$6.41 \cdot 10^{1}$
	10	$4.06 \cdot 10^{1}$	$3.06 \cdot 10^{1}$		10	$3.66 \cdot 10^{1}$	$2.88 \cdot 10^{1}$
	30	$1.51 \cdot 10^{1}$	$1.13 \cdot 10^{1}$		30	$1.39 \cdot 10^{1}$	$1.08 \cdot 10^{1}$
2nd sector (North, North-East direction)	0.5	$4.01 \cdot 10^{2}$	$3.10 \cdot 10^{2}$	10th sector (South, South-West direction)	0.5	$2.78 \cdot 10^{2}$	$2.32 \cdot 10^{2}$
	1.0	$4.82 \cdot 10^{2}$	$3.94 \cdot 10^{2}$		1.0	$3.34 \cdot 10^{2}$	$2.79 \cdot 10^{2}$
	3.0	$1.96 \cdot 10^{2}$	$1.52 \cdot 10^{2}$		3.0	$1.19 \cdot 10^{2}$	$9.79 \cdot 10^{1}$
	5.0	$9.98 \cdot 10^{1}$	$7.58 \cdot 10^{1}$		5.0	$5.96 \cdot 10^{1}$	$4.80 \cdot 10^{1}$
	10	$4.56 \cdot 10^{1}$	$3.37 \cdot 10^{1}$		10	$2.70 \cdot 10^{1}$	$2.13 \cdot 10^{1}$
	30	$1.65 \cdot 10^{1}$	$1.22 \cdot 10^{1}$		30	$1.03 \cdot 10^{1}$	$7.96 \cdot 10^{0}$

Receptor point, Distance from emission point [km]		Committed effective dose [μSv]		Receptor point, Distance from emission point [km]		Committed effective dose [μSv]	
		Adult	1-year-old children			Adult	1-year-old children
3rd sector (North-East direction)	0.5	$5.01 \cdot 10^{2}$	$3.82 \cdot 10^{2}$	11th sector (South-West direction)	0.5	$3.09 \cdot 10^{2}$	$2.57 \cdot 10^{2}$
	1.0	$5.58 \cdot 10^{2}$	$4.53 \cdot 10^{2}$		1.0	$3.84 \cdot 10^{2}$	$3.16 \cdot 10^{2}$
	3.0	$2.09 \cdot 10^{2}$	$1.63 \cdot 10^{2}$		3.0	$1.26 \cdot 10^{2}$	$1.01 \cdot 10^{2}$
	5.0	$1.06 \cdot 10^{2}$	$7.94 \cdot 10^{1}$		5.0	$6.02 \cdot 10^{1}$	$4.83 \cdot 10^{1}$
	10	$4.93 \cdot 10^{1}$	$3.60 \cdot 10^{1}$		10	$2.70 \cdot 10^{1}$	$2.12 \cdot 10^{1}$
	30	$1.72 \cdot 10^{1}$	$1.26 \cdot 10^{1}$		30	$9.95 \cdot 10^{0}$	$7.70 \cdot 10^{1}$
4th sector (North-East, East direction)	0.5	$5.20 \cdot 10^{2}$	$4.09 \cdot 10^{2}$	12th sector (South-West, West direction)	0.5	$3.54 \cdot 10^{2}$	$2.89 \cdot 10^{2}$
	1.0	$5.64 \cdot 10^{2}$	$4.62 \cdot 10^{2}$		1.0	$4.25 \cdot 10^{2}$	$3.49 \cdot 10^{2}$
	3.0	$2.07 \cdot 10^{2}$	$1.57 \cdot 10^{2}$		3.0	$1.46 \cdot 10^{2}$	$1.17 \cdot 10^{2}$
	5.0	$1.04 \cdot 10^{2}$	$7.83 \cdot 10^{1}$		5.0	$7.24 \cdot 10^{1}$	$5.72 \cdot 10^{1}$
	10	$4.71 \cdot 10^{1}$	$3.44 \cdot 10^{1}$		10	$3.28 \cdot 10^{1}$	$2.54 \cdot 10^{1}$
	30	$1.68 \cdot 10^{1}$	$1.24 \cdot 10^{1}$		30	$1.22 \cdot 10^{1}$	$9.35 \cdot 10^{0}$
5th sector (East direction)	0.5	$5.58 \cdot 10^{2}$	$4.51 \cdot 10^{2}$	13th sector (West direction)	0.5	$3.38 \cdot 10^{2}$	$2.72 \cdot 10^{2}$
	1.0	**$5.93 \cdot 10^{2}$**	**$4.87 \cdot 10^{2}$**		1.0	$4.19 \cdot 10^{2}$	$3.41 \cdot 10^{2}$
	3.0	$2.17 \cdot 10^{2}$	$1.72 \cdot 10^{2}$		3.0	$1.47 \cdot 10^{2}$	$1.19 \cdot 10^{2}$
	5.0	$1.08 \cdot 10^{2}$	$8.39 \cdot 10^{1}$		5.0	$7.73 \cdot 10^{1}$	$6.06 \cdot 10^{1}$
	10	$4.96 \cdot 10^{1}$	$3.75 \cdot 10^{1}$		10	$3.52 \cdot 10^{1}$	$2.70 \cdot 10^{1}$
	30	$1.76 \cdot 10^{1}$	$1.33 \cdot 10^{1}$		30	$1.26 \cdot 10^{1}$	$9.50 \cdot 10^{0}$
6th sector (East, South-East direction)	0.5	$5.08 \cdot 10^{2}$	$4.13 \cdot 10^{2}$	14th sector (West, North-West direction)	0.5	$2.61 \cdot 10^{2}$	$2.07 \cdot 10^{2}$
	1.0	$5.60 \cdot 10^{2}$	$4.66 \cdot 10^{2}$		1.0	$2.97 \cdot 10^{2}$	$2.41 \cdot 10^{2}$
	3.0	$1.95 \cdot 10^{2}$	$1.54 \cdot 10^{2}$		3.0	$1.07 \cdot 10^{2}$	$8.64 \cdot 10^{1}$
	5.0	$9.63 \cdot 10^{1}$	$7.49 \cdot 10^{1}$		5.0	$5.43 \cdot 10^{1}$	$4.35 \cdot 10^{1}$
	10	$4.35 \cdot 10^{1}$	$3.29 \cdot 10^{1}$		10	$2.49 \cdot 10^{1}$	$1.95 \cdot 10^{1}$
	30	$1.57 \cdot 10^{1}$	$1.19 \cdot 10^{1}$		30	$9.27 \cdot 10^{0}$	$7.14 \cdot 10^{0}$
7th sector (South-East direction)	0.5	$4.15 \cdot 10^{2}$	$3.37 \cdot 10^{2}$	15th sector (North-West direction)	0.5	$2.16 \cdot 10^{2}$	$1.69 \cdot 10^{2}$
	1.0	$5.02 \cdot 10^{2}$	$4.16 \cdot 10^{2}$		1.0	$2.47 \cdot 10^{2}$	$2.00 \cdot 10^{2}$
	3.0	$1.61 \cdot 10^{2}$	$1.29 \cdot 10^{2}$		3.0	$8.94 \cdot 10^{1}$	$7.26 \cdot 10^{1}$
	5.0	$7.90 \cdot 10^{1}$	$6.20 \cdot 10^{1}$		5.0	$4.57 \cdot 10^{1}$	$3.68 \cdot 10^{1}$
	10	$3.59 \cdot 10^{1}$	$2.76 \cdot 10^{1}$		10	$2.11 \cdot 10^{1}$	$1.66 \cdot 10^{1}$
	30	$1.32 \cdot 10^{1}$	$1.00 \cdot 10^{1}$		30	$7.92 \cdot 10^{0}$	$6.13 \cdot 10^{0}$
8th sector (South-East, South direction)	0.5	$3.23 \cdot 10^{2}$	$2.70 \cdot 10^{2}$	16th sector (North-West, North direction)	0.5	$2.40 \cdot 10^{2}$	$1.81 \cdot 10^{2}$
	1.0	$4.19 \cdot 10^{2}$	$3.53 \cdot 10^{2}$		1.0	$2.83 \cdot 10^{2}$	$2.25 \cdot 10^{2}$
	3.0	$1.49 \cdot 10^{2}$	$1.22 \cdot 10^{2}$		3.0	$1.08 \cdot 10^{2}$	$8.54 \cdot 10^{1}$
	5.0	$7.41 \cdot 10^{1}$	$5.97 \cdot 10^{1}$		5.0	$5.58 \cdot 10^{1}$	$4.36 \cdot 10^{1}$
	10	$3.38 \cdot 10^{1}$	$2.68 \cdot 10^{1}$		10	$2.58 \cdot 10^{1}$	$1.97 \cdot 10^{1}$
	30	$1.30 \cdot 10^{1}$	$1.00 \cdot 10^{1}$		30	$9.78 \cdot 10^{0}$	$7.33 \cdot 10^{0}$

Note: In the Table the values in bold letters indicate the maximum doses received by each individual representative person.

The results confirmed that the radiological impact area in the case of design basis accidents, is smaller in the new analyses than at the time of the preparation of the previous EIAR for the extension of the service lifetime of the NPP (*Chapter 5.3.5.1.3.*). While, as it was described in the environmental impact assessment for the first extension of the service lifetime of the NPP, tolerable impacts can be expected up to a distance of 6.3 km from the discharge point, based on the new analyses carried out for the present SSLE, the effect is already neutral at a distance greater than 6.0 km.

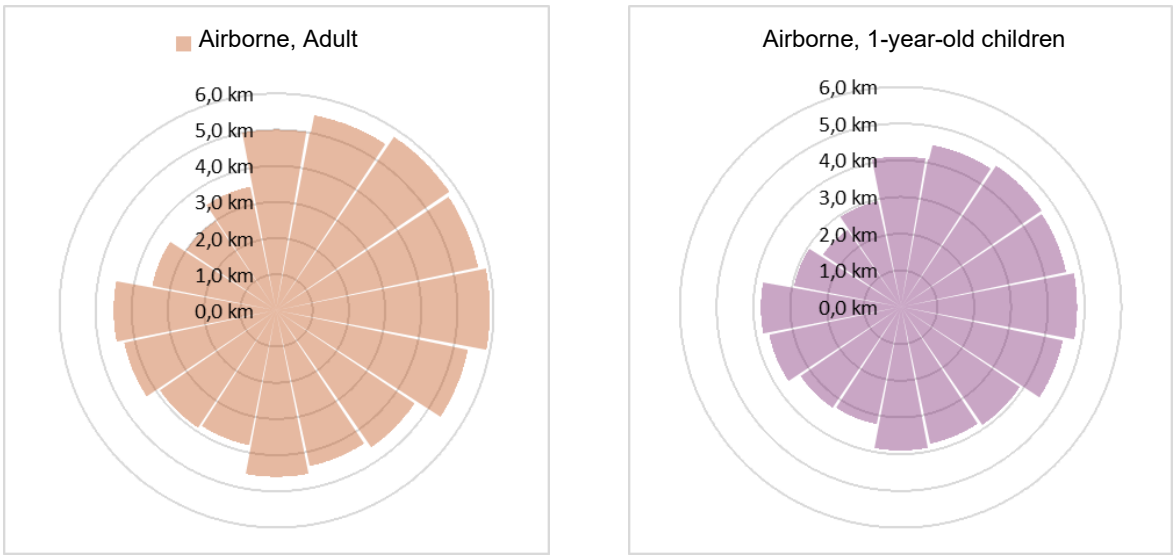


Figure 5.3.5.2.2-1. Radiological impact area for representative adults and 1-year-old children for dose values exceeding 90 μSv from gaseous discharge determined for the 3rd design basis accident (DBC4) release case

The reason for the discrepancy is that the previous and new analyses for determination of the radiation exposure of the population differ in many essential respects, due to advances in the applied methodology and analytical tools, the change in the input data of the calculations, and the decrease in the conservatism of other considerations taken into account. Such a change in the results is consistent with the development of the analytical tools and the resulting elimination of certain conservative assumptions from the analyses.

The differences between the results are acceptable taking into consideration the differences in the calculations, and the conclusions drawn on their basis regarding the radiation exposure of the population, radiological impacts and the impact area are consistent with each other.

Washout of gaseous discharges into the Danube

In the case of design basis accidents, there is no direct liquid discharge into the River Danube, so analyses for the aquatic dispersion were made assuming that in the case of design basis accidents, 19.1% of the total activity released into the air during the gaseous emission (excluding noble gases) is washed into the Danube. The washout fraction was determined based on the fraction of the emitted radioactive material that is washed into an area assumed to be 700×700 meters in size during the time that the contamination passes over the area at the given wind speed. For the calculations, this washout fraction of the source term given for atmospheric releases was taken as the source term,

Based on the calculations, the highest doses to the water exposure pathways were obtained from the accident release source term (*Table 5.3.5.1.3-1*) in the 9th case (break of a DN 492 mm hot-leg pipe in loop 4 at a thermal power of 1485 MW, with 2 sprinkler systems operating). The reason for this is that, although the amount of activity released for most radionuclides is higher in the 3rd case (break of the DN 90 mm pressurizer injection pipe at a thermal power of 1485 MW, assuming a complete black-out), the amount of release is higher in the 9th case for radionuclides that are dominant in terms of aquatic exposure pathways (e.g. radioiodine).

The calculated committed effective dose of a representative adult and a 1-year-old child in Gerjen, 10 km from the NPP is presented in *Table 5.3.5.2.2-5*. The exposure time was considered to be the time for the radioactive plume to pass along the receptor point, and during this time, the exposure pathway that gave the higher dose was swimming and water related activity. From the radionuclides released and then washed into the water, the dose contribution of iodine isotopes was the most significant, giving more than half of the total dose to adults and children.

Table 5.3.5.2.2-5. The determined committed effective doses for the washing of gaseous activity released in the River Danube in the case of the 9th design basis accident (DBC4) release scenario for representative adults and 1-year-old children in Gerjen, from different exposure pathways

Exposure pathways	Committed effective dose [μSv]	
	Adult	1-year-old children
Total	$2.88 \cdot 10^{1}$	$2.92 \cdot 10^{1}$
Water related activity – gamma radiation external dose	$2.77 \cdot 10^{1}$	
Fish consumption – internal dose	$1.07 \cdot 10^{0}$	$1.48 \cdot 10^{0}$

In the case of these radionuclides, the dose conversion factors used to determine the internal radiation exposure from fish consumption, exceed those for children compared to adults. As a result, the internal dose calculated for the former age group is also higher. However, since the internal dose from fish consumption only contributes in a small (4-5%) part to the total dose, the dose calculated for children is only about 1.5% higher than that for adults.

Based on the results of 28.8 μSv and 29.2 μSv gained for adults and 1-year-old children, it can be stated that even in this scenario examined under highly conservative assumptions, the doses remain below the value of 90 μSv/year, i.e. they do not reach the upper limit for neutral effects.

As a consequence of washing of the gaseous discharge, the calculation results for the aquatic exposure pathways cannot be added to the dose values determined for the atmospheric exposure pathways based on the gaseous emission, since the simultaneous occurrence of the two scenarios is not possible.

In the case if the emitted radioactive material is washed into the River Danube from the cloud to such a large extent, that less material will remain in the atmosphere, and thus, the doses for the exposure pathways determined due to atmospheric dispersion would also be lower. Since the doses determined for the exposure pathways related to atmospheric dispersion at most receptor points significantly exceed the values presented here, an atmospheric release scenario was taken into account when determining the radiological impact area.

Impact of potential changes during SSLE

A part of the investigations was also an assessment of the effects of the potentially changing in course of the further extension of the service lifetime characteristics, which influence the radiation exposure of the population, and which may result in changes in terms of environmental radiological effects and the radiation exposure of the population.

Concerning the dose consequences of the gaseous discharges, parameter sensitivity analyses were conducted on the meteorological data influencing the atmospheric dispersion calculations, in particular the wind speed, the precipitation intensity and the atmospheric stability categories, as well as changes in the population's lifestyle habits and the consumption of locally produced products, which influence the dose calculation. The analysis of the consequences of liquid emissions and aquatic dispersion included an examination of how changes in certain hydrological data, in particular changes in the flow rate of the River Danube and the duration of water activities (swimming, rowing, fishing, staying on the shore) and changes in the amount of fish consumption, caught from the River Danube affect the public doses.

The sensitivity analysis of meteorological data pointed out that the greatest impact on doses, is the increase in precipitation intensity. For example, analyses performed by supplementing the meteorological database with days of extreme precipitation and taking into account an operational atmospheric emission, resulted in a maximum deviation of 7.5% from the baseline for the effective doses determined for representative persons. The calculations showed that despite the assumed increase in precipitation intensities in the future, it is not anticipated that the conclusions of the analyses and the determined radiological impact area will change significantly.

Even if the population's lifestyle and consumption habits regarding locally grown food change in the future, they will not cause a very significant change (over 40%) in the dose values caused by

gaseous discharge, and accordingly, a significant increase in the impact area due to changes in the population's lifestyle and consumption habits is not anticipated. The aquatic dispersion calculations have shown that a significant decrease in water flow (from medium to low flow) can increase the effective dose determined for normal operational liquid emissions by less than three times. However, the radiation exposure level will still remain well below the dose constraint of 90 μSv/year and the upper limit of the neutral effect.

In the case of normal operational liquid emissions, the total dose was almost entirely (nearly 99%) due to the internal dose from fish consumption, so among the related input lifestyle parameters, only a change in the amount of fish consumption can cause a significant change in the total, committed effective dose. Concerning the doses received through other exposure pathways, so even doubling the annual duration of swimming or water related activities results in only a negligible increase, <1%.

5.3.5.2.3. Radiological effects of the combined operation of the Paks NPP and Paks II NPP

The combined radiological impact of the normal operation of the Paks NPP, the SFISF and Paks II NPP was also examined in the EIAR prepared for the environmental licensing of the new Paks units. In the EIAR for Paks II NPP the combined maximum dose of the three facilities did not reach the annual value of 1 μSv for adults and children aged 1-2 in Csámpa (0.154 and 0.120 μSv, respectively), and the total dose value decreases further at greater distances (up to 30 km), to below 0.003 μSv (3 nSv). The newer analyses conducted to determine the radiation exposure of the public, gave values of the same magnitude as the <0.1 μSv value in the EIAR for Paks II NPP for the doses of the stand-alone, normal operation of the Paks NPP, but slightly lower than those therein.

The reason for the difference is the continuous development of the methodologies and tools used in the analyses, the differences in the input data taken into account in the calculations, and the different degrees of conservatism in the assumptions and considerations. However, it can be stated that the cumulative dose of the combined normal operation of the three facilities (Paks NPP, SFISF and Paks II NPP) remains significantly below the 90 μSv/year dose constraint and thus, the upper limit of the neutral effect, even based on the analyses performed for the justification of the EIA for SSLE.

5.4. Impacts affecting the health condition of the population

The ionizing radiation is a natural consequence of the use of nuclear energy. Ionizing radiation affects humans throughout their lives, partly from natural and partly from artificial sources. Radiation can also be harmful, causing serious diseases, as a result of which, for example, the resulting DNA mutations can lead to diseases that develop over a longer period of time. The higher the dose of low-dose ionizing radiation is (which does not cause radiation sickness, but damages DNA), the greater the likelihood of developing a disease is (tumour or genetic disease).

Every living thing on Earth is constantly exposed to ionizing radiation. The effective dose of this radiation is 2.4 mSv/year on average on Earth, and 3.0 mSv/year in Hungary. In many places on Earth, natural background radiation is by an order of magnitude, higher than in Hungary, which is not reflected in the frequency of cancer, i.e. the exposure differences around the effective dose range of 2-3 mSv/year do not cause a detectable increase in cancer risk. (The average dose of ionizing radiation from artificial sources on Earth is 0.4 mSv/year.).

As part of the EIA for the further extension of the operational lifetime of the Paks NPP, an investigation was carried out concerning the frequency of diseases potentially related to ionizing radiation among the population living within a 30 km radius of the NPP. The analyses had to answer the question of whether, based on the observed pattern of diseases, there is a suspicion that there is an additional risk of certain diseases associated with the radiation exposure related to the operation of the Paks NPP.

The health status of the population, living in the vicinity of the NPP, was most recently the subject of a detailed investigation based on two comprehensive studies:

- Lévai Project, Development and implementation of specialized testing and evaluation programs to form the basis for the compilation of the environmental impact assessment; Final report, determination of the health status of people living in the vicinity of the site; MVM Zrt. contract number: MVM TEVH/11C00039, MVM ERBE Zrt. contract number: S 11 122 0, ERBE document identifier: S 11 122 0 007 v0 25, June 12, 2013.
- MVM Paks II. Zrt., Construction of new NPP units at the Paks site, Environmental impact assessment, MVM Paks II. Zrt. contract number: 4000018343, MVM ERBE Zrt. contract number: 13A380069000, Chapter 20: Environmental radioactivity – radiation exposure of the population living in the vicinity of the site.

The investigation formed the basis for the opinion which was conducted in two phases. In the 1st phase, the relevant data available in the Hungarian health statistical systems were processed. (The demographic data were provided by the Central Office for Public Administration and Electronic Public Services /KEKKH/, the number of deaths observed annually in settlements and the indicators of the socio-economic status of settlements were provided by the Hungarian Central Statistical Office /HCSO/, the database of registered developmental disorders was provided by the National Registry of Congenital Disorders, and itemized performance accounting data on outpatient and inpatient specialized care were provided by the National Health Insurance Fund Management.) In the 2nd phase, a survey based on primary data collection was conducted, which enabled a risk assessment adjusted for other (non-ionizing radiation) risk factors acting at the individual level.

No environmental impact, associated with health risks, had been previously detected in the vicinity of the NPP, which was also confirmed by the assessment results referred to above.

The investigation area was defined as a 30 km radius – in line with the scope of other EIA tasks. Within this area it was possible to confirm, by measurements and model calculations based on measurement results, that no ionizing radiation capable of causing significant biological effects was released into the environment from the NPP. The investigation area represents a potentially exposed population. Therefore, in the investigations, the population within a 10 km radius of the NPP (as the primary potential impact factor), those living in the 10-20 km zone (as secondary potential impact factor) and the population living in the 20-30 km zone (as the reference population reflecting local conditions) were assessed separately.

5.4.1. Examinations of phase 1

In the course of the assessment of mortality and morbidity conjectures essentially examined the relationship between the expected and observed number of cases was examined. The first step of this analysis was to generate standardized ratios by age, sex, and year of the investigation, using indirect standardization to obtain frequency data that show the risk independently of the confounding effect of demographic composition. Then, using distance trend analysis, it was examined, whether the location of the Paks NPP acts as a point source of health-damaging effects (whether the risk has increased in the vicinity of the NPP and has decreased with distance from it). The latter analyses were supplemented by an assessment of the effect of socio-economic status, which plays a role in the development of the diseases studied.

In summary it can be said that the assessment showed that the population living in the investigated area could be characterized as having a favourable health status, or a health status similar to that observed in the reference populations in almost all endpoints.

The following endpoints raised the theoretical possibility of increased risk associated with the power plant based on statistical indicators:

- mortality due to malignant tumours of the colon,
- mortality caused by hypertension related diseases,
- occurrence frequency of developmental disorders of the alimentary canal,
- morbidity due to malignant tumours of the colon,
- morbidity caused by hypertension related diseases,
- morbidity due to ischemic heart diseases,

- morbidity due to cerebrovascular diseases,
- morbidity due to circulatory system diseases,
- morbidity due to other musculoskeletal developmental disorders,
- morbidity due to spinal cord origin muscular atrophy.

In relation to the above, it is important to highlight the following:

- Morbidity caused by circulatory system diseases summarizes the cases of hypertension disease, ischemic heart disease and cerebrovascular diseases, and therefore cannot be considered an independently evaluated endpoint indicating a potential increase in risk.
- The risk excesses registered in course of specialized care caused by certain circulatory system diseases may be explained by the fact that specialists can take on a more significant role in the care of those living close to Paks, whose role is taken over by primary general practitioners in the case of those living further away. In principle, the more unfavourable cardiovascular risk factor pattern (smoking, obesity, sedentary lifestyle) of those living near the power plant could also explain the increase in local risk. However, due to the decreasing local risks depending on the distance from Paks, an explanation based on easier access to specialized care is more likely.
- The ionizing radiation is not included among the etiological factors of cardiovascular diseases, which also supports that the increase in local risks is not due to excess exposure to ionizing radiation.
- Among the 82 endpoints examined there were 8 summary indicators (tumours in total, total cardiovascular diseases, total gastrointestinal diseases, and violent deaths together) were included. Of the 74 detailed indicators, 6 dealt with chronic cardiovascular diseases, whose etiological factors did not include low doses of ionizing radiation. Taking these into account, statistical evaluations were carried out on 68 relevant endpoints. The number of statistical artifact results for such a number of analyses is 68×0.05=3.4. Based on this (assuming the equal number of tests producing apparently significant differences in the positive and negative directions), the expected number of statistically significant differences that could be explained by chance is 3.4 (1.7 risk increases and 1.7 risk decreases).
- Mortality due to malignant tumours of the colon (high Paks risk based on 63 cases), morbidity due to spinal cord origin muscular atrophy (high Paks risk based on 8 cases) and morbidity due to malignant tumours of the colon (high 0-10 km zone risk based on 136 cases) were highlighted based on 1-1 statistically significant increase in risk, and the incidence of developmental disorders of the alimentary canal and morbidity due to other musculoskeletal disorders were highlighted based on 2-2 significant statistical tests (high Paks risk based on 13 and 1936 cases and high 0-10 km zone risk based on 17 and 2599 cases). There is certainly a statistical artifact among these. (We observed 7 significant increases in risk compared to the expected 3.4). However, based on the data available in the 1st, it is not possible to distinguish between statistical artifacts and true accumulation endpoints. This requires an assessment of the etiological relationships of the diseases and knowledge of the intensity of risk factors observed in the examination area. The latter was particularly important in the case of colorectal cancer, because this tumour showed a local increase in risk in both mortality and morbidity analyses registered in specialized care.
- The reliability of the basic data of the endpoints showing an increase in risk is not uniform. Some of the diseases registered in specialized care are the reference diagnosis used during examinations (they are only registered based on suspicion of the disease). The reporting discipline of developmental disorders shows regional variability. The diagnosis of cancer-related causes of death, based on histological diagnosis, can be considered the most reliable of the basic data of the indicators showing an increase in risk. This consideration also supported the need for a more accurate exploration of the incidence relationships of colon cancer.

5.4.2. Phase 2 of the examination with involvement of general practitioners

In order to evaluate the theoretical possibilities of increased risk associated with the power plant identified in the course of the 1st examination phase, the 2nd phase examinations were carried out with the involvement of general practitioners.

During the course of the examination, the lifestyle risk factors acting at the individual level cause interpretation difficulties if the incidence of individual diseases cannot be cleared from the effects of lifestyle-related confounding factors (e.g. smoking, alcohol consumption, accumulation within the family, etc.). That is why, the analyses based on aggregated data, therefore, had to be supplemented with primary data collection in the examination area, which described not only the health status of the residents, but also their risk profile per person. The development of such a database is conceivable with the help of general practitioners. To this end, a cooperative general practitioner service had to be organized, because general practitioners know those basic risk factors that have a significant impact on the development of the diseases examined in the program. With their help, both the health status and the risk profile can be recorded while respecting data protection rules, ensuring full coverage, which is important for the assessment, and in the required quality.

The level of education (as a proxy indicator describing the general social-economic status), the regular smoking, the occupational radiation exposure, diabetes, the ischemic heart disease and the hypertonia diseases, and family history in relation to occurrence of cancer were confounding factors considered in the analyses. In the selection of the control group, the general practitioners asked adults, not suffering from cancer, matched in age, gender and educational level to participate. The (potential) exposures of the residential environment could be approximated by the distance of the examination participants' residence from the power plant. Residents living more than 20 km from Paks, were considered unexposed, while those living closer were considered (potentially) exposed.

Within the examination, an answer was sought to determine whether there was a relationship between the incidence of cancer diseases and the distance between the residence and the power plant, which correlates with potential NPP exposure. The calculated relationship metric number was the odds ratio, which vividly shows how many times higher the chance of cancer disease occurrence is among people living near the power plant than in the reference population living further away.

The purpose of the assessment was to assess the frequency of biological effects related to ionizing radiation among people living in the vicinity of the NPP.

Such an examination approach was used, that allowed, by correcting the effects of risk factors affecting the development of tumours, to quantify the capability of the exposure from the power plant alone to influence the cancer risk. The examined exposure (the dose of ionizing radiation released into the environment from the power plant) was estimated, instead of direct measurement data, using the distance between the residence of subject of examination and the power plant. The induced health damage, was the incidence of cancer registered by the general practitioner. The other risk factors controlled, were the following: age, gender, education level, smoking, occupational radiation exposure, familial tumour clustering, diabetes, hypertonia, ischemic heart disease. During the course of the examination, the general practitioners continued to collect data in settlements located more than 30 km from the power plant in 3 counties. In course of the processing, the effect of the risk factors was analysed by tumour type. A description of the case and control populations was prepared, and the role of each risk factor in influencing risk was determined using multivariate logistic regression.

In summary, it can be stated that the assessment found no increased risk of cancer diseases among people living near the NPP.

5.4.3. Anticipated impacts in course further extension of the operational lifetime

In the course of normal operation, the radiological impact is neutral with regard to atmospheric and liquid emissions, because the combined maximum total doses of the three Paks facilities

(Paks NPP, SFISF, Paks II NPP) remain two orders of magnitude below the upper limit of the neutral value in the case of normal operational atmospheric emissions.

The highest combined impact of liquid emissions is 0.154 μSv/year for children aged 1-2, and 0.204 μSv/year for adults. Based on the applied and highly conservative approximations, the normal operational mode of the power plant does not pose a risk greater than neutral (exceeding 90 μSv) for the population.

For this reason, the same health effects are anticipated after the further extension of the Paks NPP's operational lifetime and the commissioning of Paks. II. NPP as in course of the Paks NPP's previous operation. In other words, the current operation of the Paks NPP and the SFISF had a neutral impact on the health of the population living in their vicinity, which will not change even if Paks II NPP starts operating – in accordance with the plans known so far.

It was not possible to detect any health loss among the people living in the affected area that is not present in the control groups and can be attributed to ionizing radiation. Based on the measurements and conservative model calculations, Paks NPP and the SFISF caused an environmental load that was orders of magnitude smaller than that determined by the authority dose constraint. According to the model calculations, the commissioning of Paks II NPP will not change this situation either. Due to the extremely small population exposure compared to the dose constraint, it is not possible to define an affected area in the usual way in environmental epidemiological studies. There is simply no such additional exposure to which the geographical extent of the impact area could be adjusted.

The stochastic health effects of low-dose ionizing radiation, appear with a significant latency in the case of tumours and genetic diseases. However, in the case of developmental disorders, the effect appears within a period corresponding to the length of pregnancies. For this reason, it is important to regularly perform a risk analysis for developmental disorders, and therefore it is important to operate a continuous monitoring system in order to detect health damage with a long latency. This is why regular and long-term health monitoring is carried out in the vicinity of NPPs.

The majority of diseases caused by ionizing radiation are life-threatening, or cause a significant deterioration in the quality of life, even with treatment. For this reason, such strategies in this area that focus on the subsequent mitigation of the damage that has occurred cannot be followed. For this reason, it is justified that dose constraint are extremely strict. (The dose constraint of 90 μSv/year per power plant are very low even compared to the 0.4 mSv/year effective dose that occurs as a side effect of average medical care.) And for this reason, it should be evaluated very positively that the Paks NPP has a very small burden on its environment in course of its operation, even compared to the dose constraint.

5.5. Radiation exposure of the wildlife

As part of the EIA of the Paks NPP SSLE, the latest comprehensive assessment of the radiation exposure of the wildlife, the findings made in the EIAR prepared for the construction and operation of the Paks II NPP, and the processing and evaluation of the studies presenting the radiation exposure of emission, meteorological and living organisms prepared since the Paks II NPP related EIAR were prepared. The targeted sampling tests carried out in 2024 made it possible to monitor further the current radiological state of the wildlife. This enabled the examination of the radiation exposure of the wildlife and the estimation of future risks within the framework of the studies for further extension of the operational lifetime of the Paks NPP in accordance with international recommendations.

The sensitivity of living organisms to ionizing radiation, varies within very wide limits, which results from the fact that all living organisms from the lowest levels of organization to mammals were the subject of the assessment. According to research based on international recommendations and scientifically sound estimates, the no-effect dose rate can be determined as 10 μGy/h for a wide range of living organisms. Therefore, as a conservative approach, the dose rate of 10 μGy/h was taken into account for all biota included in the survey. As long as the dose rate for any biota remains below this value, no effects related to radiation exposure should be expected.

The operational emissions of the Paks NPP occur primarily through the chimneys into the atmosphere and through the warm-water channel into the River Danube in the form of liquid emissions. According to the prevailing wind direction, the radiation exposure from gaseous emissions can be assumed to be mostly in the south and south-east directions from the power plant, while the radiation exposure from liquid emissions is most likely to occur in the section of the River Danube directly below the warm-water channel.

From the point of view of the performed examinations, the radiation exposure of wildlife from natural sources could be defined as the baseline condition, which is independent from the emissions of the power plant, but at the same time affects the wildlife in the same way as the radiation exposure from the power plant. In the terrestrial environment, the radiation exposure of wildlife is determined to a large extent by natural radioactive isotopes originating from the soil. Regarding the background radiation exposure of terrestrial wildlife living in the vicinity of the NPP, it can be said that its level is below 0.5 µGy/h for the majority of species, which is 1/20 of the uniformly defined dose without effect of 10 µGy/h. The highest values occurred in the case of mosses, but these were also below the 5 µGy/h value.

Regarding aquatic habitats, the determining living space is the water itself, which mostly contains only small amounts of dissolved earth' crustal material. This is especially true for the U and Th series. As a result of this, their activity concentration in the water is 3-4 orders of magnitude lower than in soil. The radiation exposure of fish, water birds, amphibians and aquatic mammals can be characterized by a dose rate typical of terrestrial life. In the case of mussels, crabs and snails, the fact that these organisms are typically bottom-dwellers, therefore their habitat and nutrition are more tied to the sediment, obviously plays a major role in the values approaching 10 µGy/h.

As a result of human activity, the appearance of fission and activation products from atmospheric nuclear weapons tests in the 1950s and 60s, as well as the Chernobyl reactor accident, in the vicinity of the Paks NPP, and to a decisive extent, their washing out by precipitation, are also part of the radiation exposure of wildlife. However, from the perspective of the assessment carried out, the main issue is the direct radiological impact of the Paks NPP on the wildlife, which is also present in the environment due to operational emissions. In course of the assessment of the current impacts associated with normal operation, special attention was paid to those isotopes that are operationally emitted from the power plant (e.g. ^{3}H, ^{14}C, ^{54}Mn, ^{58}Co, ^{60}Co, ^{134}Cs, ^{137}Cs).

For its evaluation, it was necessary to examine the condition of the releases and those meteorological factors that influence the extent of washout and fallout of radionuclides in the vicinity of the power plant. The determining factors in this case are the emitted activity, the characteristics of precipitation, wind and atmospheric conditions. It established that no significant changes occurred in the period between 2011 and 2022 regarding the examined isotopes. Examining the annual precipitation amount, apart from the wetter year of 2010, no major fluctuations can be observed, which implies that the intensity of leaching with precipitation did not change significantly or in a trend-like manner during the examined period.

Another determining factor of the intensity of the fallout is the frequency and distribution of atmospheric stability conditions, characteristic for this area. There was no significant shift in the atmospheric stability characteristics during the examined period, and the frequency of unstable states promoting fallout and the average of the associated wind speeds did not change significantly either.

The fallout rate modelled using the annual average emission data and annual meteorology in the case of ^{137}Cs after a distance of 500 m from the power plant decreases by an order of magnitude. It can be stated that no significant difference in terms of radiation exposure of the living world could be identified in either the emission values or the meteorological characteristics for the nearly 10-year period since the preparation of the EIAR for Paks II NPP, thus the statements made in the EIAR of Paks II NPP regarding the emissions and fallout are still correct.

As a result of the radioanalytical examination of 2024 performed based on sampling, it was possible to establish that among the artificial gamma-emitting isotopes the ^{137}Cs was generally detected in environmental media and living organisms, regardless of the place and time of sampling. Taking into account the $^{134}Cs/^{137}Cs$ ratio formed in course of nuclear power generation, the major part of the ^{137}Cs measured in the samples is not the result of emissions from the

Paks NPP, but is a consequence from fallout of atmospheric nuclear weapons tests and the Chernobyl reactor accident.

One of the most significant isotopes, with a longer half-life in the emissions of the Paks NPP, is ^{14}C. In certain habitats most affected by the emissions, directly below the outlet of the warm-water channel and in the vicinity of the A9 measurement station, values slightly exceeding the natural background radiation were observed, to which the ^{14}C contribution of a similar magnitude could be identified in previous testing program as well. Previously, well-measurable ^{3}H concentrations occurred in the River Danube section below the warm-water channel. However, during the 2024 campaign, ^{3}H concentrations originating from natural precipitation could be measured in all samples. It could have been also established in the case of alpha-emitting isotopes that, with the exception of soil samples, all samples were below the detection limit of 0.01 Bq/kg. At the same time the results of the soil samples were consistent with the typical values from global fallout.

The Emission Control Laboratory of the Paks NPP continuously measures the power plant's gaseous discharges. This was used to estimate the radiation exposure of the living world in relation to the individual habitats. Based on the results, it can be stated that the contribution of the power plant to the wildlife is practically negligible, i.e. it has a neutral effect in addition to the global and Chernobyl radiation exposure, considering that it represents a significantly smaller dose contribution compared to the global background. There is no significant difference between the dose rates received for individual groups of flora and fauna in the case of either source.

The current radiation exposure of aquatic life from anthropogenic sources, similarly to that of terrestrial wildlife, primarily originates from the isotopes ^{137}Cs, ^{90}Sr, ^{239}Pu and ^{241}Am that fell out as a result of nuclear weapons tests, as well as from the isotope ^{137}Cs that settled during the Chernobyl reactor accident. Furthermore, in the River Danube also the radioactivity from the liquid emissions of Paks NPP shall also be taken into account. It was found that the dose exposure of individual aquatic organisms is in the order of 10^{-6}-10^{-3} µGy/h. The power plant emission and the global artificial background are of a similar order of magnitude. Overall, it can be said about the radiation exposure of aquatic life as well that the dose rate from artificial sources is orders of magnitude lower than the reference level of 10 µGy/h. On this basis, it can be stated that the radioactive emissions of the power plant have a neutral effect on aquatic life.

Concerning the estimate for the future, it is determined by the predictability of expected emissions. A good opportunity for this is to examine how the emissions of the power plant have developed in the past. Can an unambiguous trend have detected, indicating an increase/decrease, or can the long-standing operational culture present a predictable stability that is also reflected in the emissions. The isotopes that are considered to be the most important from dosimetry point of view, move in a relatively narrow range in magnitude. A possible increasing trend related to the aging of the units is not observed. It can be assumed, that the atmospheric emissions will not change significantly for the period of further operation, and even a small reduction in emissions is conceivable for some isotopes. This would also result that the concentration of radioisotopes accumulated in the environment over decades will be possible to characterize by a decrease caused by radioactive decay, which means at the same time an even lower level of anthropogenic dose for wildlife.

Concerning the discharges into the River Danube, a similar line of thought can be drawn based on the data. The extended operation of the power plant will not result in significant increase of emissions. Based on the above assessments, no significant increase is anticipated in terms of radiation exposure to the wildlife, despite the fact that in principle, such isotopes with long half-lives, as ^{137}Cs, will accumulate in the soil over time due to regular emissions. Namely the power plant makes a negligible contribution to such soil contamination compared to the current remnants of previous global and Chernobyl contamination, so the total contamination will also show a decreasing trend in course of the further operation. The former was also confirmed by the results of sampling tests performed to monitor radiation exposure to wildlife, carried out in every five years since 2010 and in 2024 within the framework of the SSLE EIA.

The background radiation exposure of the wildlife from natural sources ranges from a few tenths of µGy/h to a few µGy/h, depending on the species and habitat. The estimated contribution of the power plant to the radiation exposure of terrestrial and aquatic life was only in the range of

10^{-3}-10^{-6} µGy/h. This seemingly insignificant excess will remain the same during the further operation of Paks NPP, since the level of atmospheric and aquatic emissions is estimated to remain unchanged. After the cessation of the power generation and the treatment of liquid radioactive waste, even this low radiation exposure of aquatic life will cease, while in the case of terrestrial life it will decrease significantly as the fission and corrosion products with longer half-lives accumulated in the soil will decay. In the course of the further extension of the operational lifetime period, the same neutral, no-effect dose exposure condition will be achieved for wildlife, which is also valid for the current situation.

The impact of the Paks II NPP can naturally only be estimated using the design parameters and taking into account the real (anticipated) local impact factors. The predicted impact on the wildlife of the Paks environment, the dose rate value without effect (10 µGy/h) must be met by both power plants operating simultaneously. Based on the annual emission inventory and the Paks meteorological data, the presumed spatial distribution of the radioactive material released into the terrestrial environment bordering the operating area could be estimated. This includes, on the one hand, the radioactivity of the surrounding air, and, on the other hand, the examination of the soil as a receptor. During the course of the examination, the locations characterized by the maximum concentration were identified. The data valid for these were used to estimate the radiation exposure of the reference living organisms. Since the chimneys of the two units are not too far apart, the spread of the emitted radioactive material can be considered to originate from the same location. In the EIAR of Paks II NPP, it was stated that the dose rate data estimated as the impact of the new units tend to be higher compared to the impacts of the Paks NPP, which can obviously be explained by the conservative nature of the design emission data provided, and furthermore the higher installed capacity also contributes to the greater impact. The results of the analyses carried out in course of the review are typically lower than those of the previous calculations and are still negligible in terms of the radiation exposure of living organisms, at 10^{-4} µGy/h.

It can be stated that in terms of atmospheric emissions, the Paks NPP, together with the emissions from Paks II NPP will not have any impact on terrestrial wildlife in course of the period of the operational lifetime extension, i.e. their impact can be assessed as neutral.

99.99% of the total activity emitted by the planned new units, is tritium, which is very close to the liquid emission inventory of the Paks NPP justified by regular measurements, and on the other hand, it is also obvious that the planned emission can be forecast far below the limit value.

If compared to the natural background, organisms living near the riverbed suffer the highest relative dose rate contribution. However, the estimated total dose rate contribution of sediment-dwelling organisms most exposed to the accumulating artificial isotopes is only in the order of 10^{-3} µGy/h. The sum of the estimated dose rates (the four units of Paks NPP and the two units of Paks II NPP) is roughly 2-3 orders of magnitude below the estimated background radiation exposure to aquatic life and is at least further 1-2 orders of magnitude lower than the reference level of 10 µGy/h recommended by the ICRP (International Commission on Radiological Protection). Based on these, it can be stated that, at the current level of knowledge, the further extension of the Paks NPP's operational lifetime concerning the liquid emissions, is neutral for life, even in the case of the common operation of the two power plants. Thus, the neutral no-effect dose rate condition valid for the current state, will be fulfilled.

In terms of operational accidents, no significant impact on the surrounding wildlife is anticipated as a result of potential operational accident, and furthermore, no transboundary impacts are expected.

Overall, it was determined that 90-99% of the dose rate affecting the wildlife in the Paks NPP environment comes from natural sources. The dose contribution associated with the operation/emissions of the Paks NPP is negligible, has a neutral effect, and does not pose a comprehensible risk to the wildlife. The radiological impacts on wildlife have always been negligible, and this is expected to continue during the period of the SSLE. This statement is also valid in the case of the common operation of the two power plants.

Since the current emissions do not have an impact on the surrounding wildlife, no direct impact area can be delimited. Thus, nor can an indirect impact area be delimited. In the areas examined,

the level of radiation exposure does not reach a level that would spread further through any impact process and cause changes in the state of wildlife in other areas.

5.6. Generation and management of radioactive waste and spent fuel assemblies

5.6.1. Generation, management and storage of radioactive waste

Pursuant to Section 38 (1) of Act CXVI of 1996 on atomic energy, in course of the licensing procedure for the SSLE, it shall be proven that the safe disposal of the generated radioactive waste and spent fuel is ensured, in accordance with the latest proven scientific results, international expectations and experience. The activities related to the final disposal of radioactive waste and the temporary storage of spent fuel fall within the remit of PURAM, the body designated by the Government.

In the course of operation of the NPP, solid and liquid low-, intermediate and high-level radioactive waste is generated, which is temporarily stored in the NPP until it is transferred to the final repository. The majority of solid radioactive waste is placed in 200-liter steel barrels in a compressed form – in the case of non-compressible waste, uncompressed. The liquid radioactive waste is collected in tanks at the NPP. The radioactive waste can only be permanently disposed of in a solid form; therefore, the liquid waste is also solidified at the NPP before being transferred to the final repository.

5.6.1.1. Generation, management and temporary storage of radioactive waste generated in course of preparation for the SSLE

The generation of low, intermediate and high-level radioactive waste resulting from certain reconstruction works presented in *Chapter 2.2.2.5.*, planned in the framework of the preparation for the further extension of the operational lifetime of the Paks NPP and the activities and modifications planned for the further operation, shall also be taken into account. Based on the performed estimates, the following reconstructions affecting the civil engineering structures, technological systems and equipment of the NPP typically result in the generation of radioactive waste:

- minor structural reinforcement of the operational main buildings,
- replacement and repair of equipment inside the reactor (interim rods, reactor basket bolts),
- replacement of control rod drives,
- replacement of main cooling pump disc spring assemblies,
- type change and replacement of mechanical equipment (e.g. valves, pumps),
- replacement of certain electrical, instrumentation and control and chemical equipment,
- replacement of equipment related to radioactive waste management technologies (^{60}Co removal-complex decomposition technology, Liquid Wastewater Treatment /FHF/ technology).

The reconstruction works carried out in course the preparation of the further extension of the operational lifetime, affecting the civil engineering facilities and technological systems of the NPP and, which are planned to be carried out between 2026 and 2037, will result in the generation of a total of 1870 t of radioactive waste, of which 1810 t will be low and intermediate-level radioactive waste and 60 t is high-level radioactive waste. (The volume of waste to be disposed of, will be determined by the physical form of the waste generated /compactable, metal, concrete, etc./.)

Based on the annual rate of generation of radioactive waste related to the preparation of the further extension of the operational lifetime, it can be stated that the largest quantities (360-605 t per year) are expected between 2030-2032, the majority of which can be classified as low and intermediate-level (*Figure 5.6.1.1-1.*). In the following years, the total amount of radioactive waste generated, will vary between 10-67 t. As it is indicated in the annual data the amount of high-level waste accounts for only a few, at most 18 20%, of the total annual amount of radioactive waste.

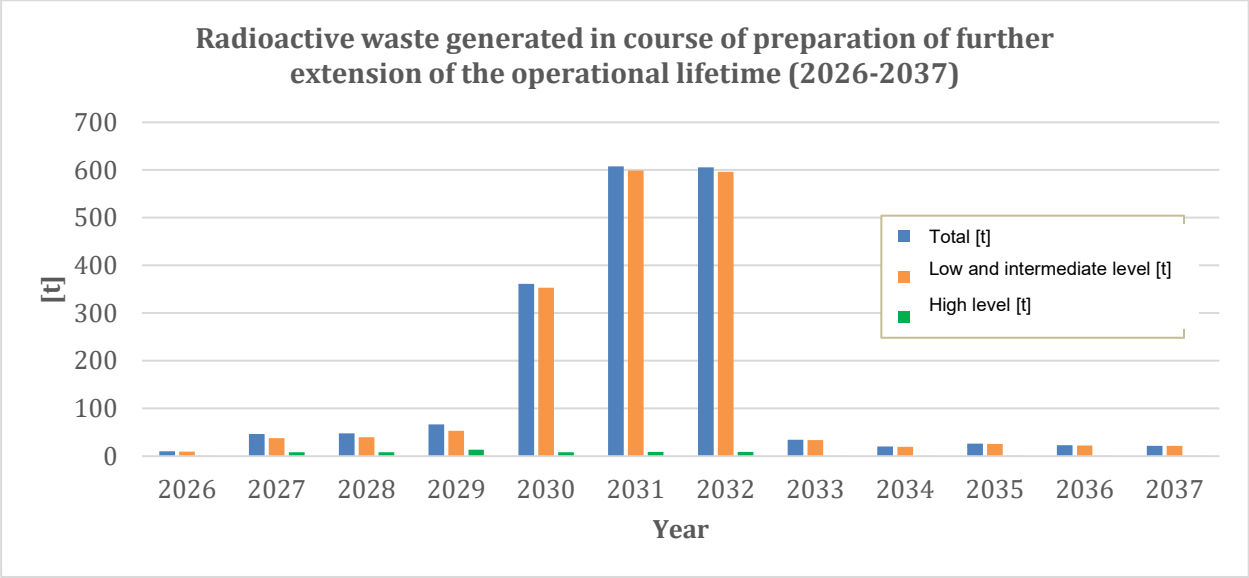


Figure 5.6.1.1-1. The estimated annual amount of radioactive waste anticipated to result from the implementation of the Paks NPP further extension of the operational lifetime

According to *Figure 5.6.1.1-1.* in the period 2030-2032 the estimated above amount of waste generated in course of preparation of the SSLE, will significantly exceed the usual annual amount of operational waste generated. Therefore, in order to assess the environmental impacts, a more detailed examination of this critical period was carried out. Concerning the activities summarized in *Table 2.2.2.5-1. of Chapter 2.2.2.5.*, more than 90% of the low and intermediate level waste will be generated in course of the following four reconstruction works:

- minor structural reinforcement of the main operational buildings (863.5 t, ~3500 barrels),
- replacement of hermetic area cable penetrations and cables (502 t, ~4700 barrels),
- replacement of control rods and safety protection assembly drives (93 t, ~460 barrels),
- reconstruction of the cooling pool lining and the carbon steel and concrete elements underneath (150 t, ~600 barrels).

In the case of reconstruction works to be carried out in the controlled area, the entire amount of waste generated is conservatively considered as radioactive waste. However, based on operational experience, a significant part of the waste generated in the controlled area, can be exempted. Based on practical experience and theoretical considerations, it can be assumed that a significant part of the waste generated will be exempted based on normal release practice or individual exemption permits and can be treated as conventional waste when transported out of the controlled area.

As a more realistic estimate of the anticipated amount of radioactive waste, the following assumptions can be made with respect to the above waste streams, which account for 90% of the waste:

- In course of the structural reinforcement of the main operational buildings, construction waste will be typically generated, i.e. concrete rubble. The inner surface of the walls of the controlled area is covered with decontaminable coatings. By decontaminating these before demolition work, the activity content of the generated waste can be expected to be reduced below the exemption limit. In the case if the volume of the affected building structure is contaminated, then the above result cannot be achieved by decontamination, therefore 10% of the estimated waste volume (86.4 t, ~350 barrels) may be radioactive waste.
- The surface of cables generated in course of removal of hermetic area cables and cable penetrations will most likely be contaminated with radioisotopes to a greater or lesser extent. In order to reduce the amount of radioactive waste, the radiological qualification of the dismantled cables shall be carried out within the framework of the reconstruction project, based on which the cables can be exempted without further treatment or following decontamination. In the case if decontamination cannot be implemented or is ineffective,

then the cable insulations can be removed and treated as radioactive waste, and the conductive metal can be exempted. As a result of these activities, the amount of radioactive waste can be reduced to 10% of the generated waste volume (50 t, 470 barrels).

- In the case of drives of the control and safety protection assemblies, based on practical experience, following decontamination of the drives, 70% of the waste can be exempted, while 30% (28 t, 115 barrels) will remain as radioactive waste.
- In order to substitute the reconstruction of the spent fuel pool lining and the carbon steel and concrete elements underneath, the development of a non-metallic cover repair method has begun. In the event of the success of the project, which is based on international experience, the expected amount of waste from the reconstruction will not have to be taken into account. Given the international references, it can be assumed that a significant part of the linings can be repaired with this solution, and only a partial replacement of the lining will be necessary. The amount of waste generated can be estimated at 20% of the waste volume of the entire reconstruction (30 t, ~120 barrels).

Taking into account the above, the anticipated amount of low and intermediate level radioactive waste to be generated in course of the preparation of the further extension of the operational lifetime, will be 375 t (~1750 barrels), of which approximately 1000 barrels will be generated between 2030-2032.

Concerning generation of high-level radioactive waste that can be anticipated to be generated in course of the replacement of the internal equipment of the reactor (interim rods driving the control and safety protection assemblies (215 pcs, 9 t), replacement of the reactor basket bolts (0.4 t) and the reconstruction of the cooling pool lining and the carbon steel and concrete elements underneath (50 t). In the latter case, as a result of the application of the non-metallic cover repair technology, only 20% of the estimated waste volume (10 t) can be anticipated even in the case of high-level waste. The interim rods for driving the control and safety protection assemblies are not entirely high-level waste, but only a part of them was activated in course of their use. Consequently, the amount of high-level waste can be significantly reduced by cutting the interim rods. Without cutting, one interim rod occupies an entire high-level waste storage well, i.e. 215 wells would be required for temporary storage of the waste. After cutting, 4-5 high-activity parts of interim rods could be placed in one storage well, thus only requiring 43 storage wells.

The collection, classification, treatment and preparation of radioactive waste generated in course of preparation of the further extension of the operational lifetime are planned in accordance with the valid procedures of the NPP and integrated into the existing treatment processes.

Considering that the waste generated during the preparation of the SSLE will be generated within a relatively short time and will significantly exceed the usual annual waste volumes, it is necessary to ensure their temporary storage prior to final disposal.

The utilization of the temporary storage capacities of low- and intermediate-level solid radioactive waste on site is nearly 90% according to data from 2025, so the temporary storage of the expected waste volumes, will require a release from the storage capacities.

On the power plant site there is a capacity for storage of 11,355 pcs 200-liter barrels containing low and intermediate level waste in designated storage locations. As of December 31, 2025, 10,405 barrels were stored in these storage locations. The free capacity still allows for the temporary storage of 950 barrels, so in this case as well it will be necessary to increase storage capacity in order to ensure the temporary storage of radioactive waste arising from normal operation and waste generated in course of preparation of the further extension of the operational lifetime.

The normal operation of cementing technology is scheduled to be started in 2029. This technology will produce so-called compact waste packages, in which 4 pcs 200-liter metal barrels will be placed into a thin-walled, reinforced steel container (*Figure 5.6.1.1-2.*). The space between the barrels will be filled with a cement paste mixed with liquid radioactive waste, so the dead space between the containers will also be filled with radioactive waste. After the production and quality assurance processes, the waste packages will be delivered to the National Radioactive Waste Repository (NRWR) operated by PURAM.



Source: Webpage of PURAM (rhk.hu)

Figure 5.6.1.1-2. The compact waste package containing low and intermediate-level radioactive waste, formed with a steel container

The NPP plans to produce 400-500 compact waste packages per year by means of the cementing technology, which means placing 1600-2000 barrels in compact waste packages and transporting them for final storage. Thus, in period between 2029-2032, 6400-8000 barrels containing low and intermediate level waste will be transported from the plant. In parallel with this, a maximum of 3500 barrels of waste are expected to be generated in course of normal operation in the period between 2026 and 2032, and 1500 barrels of radioactive waste will be generated in connection with the activities related to further extension of the operational lifetime, i.e. a total of 5000 barrels. By the operation of the cementing technology, thus it will be possible to ensure the capacities required for the temporary storage of low and intermediate level solid waste.

In the case if the generation rate of radioactive waste would exceed this planned rate for an unforeseen reason, or the processing will not be able to operate at the planned capacity, then there is a possibility to establish an alternative temporary storage capacity. This could be done after the modification of an existing storage building, or a part of the building outside the controlled area of the NPP and obtaining a radiation protection authority license. Paks NPP already has a reference for such a solution, as it has previously received a license for the storage of large size and slightly radioactively contaminated equipment in the referenced storage building. Consequently, it can be realistically assumed that the storage of 500-1000 pcs 200-liter barrels containing very low-level waste can be licensed following the appropriate conversion of the building. Thus, the appropriate temporary storage of low- and intermediate-level waste can be ensured under all circumstances.

In addition to all this, the MVM Paksi Atomerőmű Zrt. has made significant efforts since 2015 to reduce the amount of radioactive waste on the site. By recycling the low and intermediate-level solid waste and individual exemption of the very low-level waste, a storage capacity of 2,452 barrels could be released, which corresponds to waste generated in course of 5-6 years of normal operation. The continuation of this activity may also be important from the point of view of the temporary storage of waste generated in course of preparation of further extension of the operational lifetime.

The temporally storage of the high-level waste – depending on their size – will be performed either in tube wells located in the reactor halls or in shielded containers suitable for storing 200-liter barrels in reserve rooms A216/3 and A216/6 and in the reactor halls.

In total there are 1,114 tube wells, i.e. 222.8 m^3 of storage capacity available on twin-units 1-2, and 3-4 of the NPP for the disposal of high-level radioactive waste generated in course of the operation. From the 222.8 m^3 storage capacity, 112.7 m^3 was used by 1 January 2025. In course of the last 15 years, the average amount of high-level waste generated was 1.4 m^3/year, so by the end of the 50-year operational lifetime generation of a further 22 m^3 of high-level radioactive waste should be conservatively anticipated. Consequently, nearly 85 m^3 of storage capacity is available for the temporary storage of high-level waste generated during the period of preparation and implementation of the further extension of the operational lifetime.

The high-level waste containing low- and intermediate-level components as well, that can be stored in tube-wells, include interim rods removed from reactors. Their quantity can be

significantly reduced by the above-mentioned cutting of the removed rods, so that 80% of the storage wells used for storage of the interim rods can be released, i.e. approx. 40 m^3 of storage capacity can be obtained. Thus, by the storage capacity released it can be ensured that – with the additional 20-year extension of the operational lifetime – the temporary storage of high-level waste generated during a total of 70 years of operation could be also solved.

5.6.1.2. Generation and management of radioactive waste generated during further extension of the operational lifetime

An overview is given in *Table 5.6.1.2-1.* on the low- and intermediate-level waste generated in connection with the operation of the NPP as of 1 January 2025. Based on the annual generation rate of waste quantities resulting from the normal operation of the NPP as indicated in the table, approximately 90 m^3 of solid waste (approximately 450 pcs of 200 l barrels) is generated annually, to which an additional 10 m^3 (50 barrels) is expected from the operation of the FHF technology. Thus, 500 barrels are anticipated to be generated annually.

Among the solid waste, there is also a large size of solid waste to appear. This radioactive waste cannot (or it is not practical to) be placed into 200 l barrels. However, the annual amount is not significant.

Among the solid waste, there are cesium and other filter cartridges, which are later placed into special circular storage containers. This type of waste is also generated in low amounts over the entire operational period. Thus, the annual amount of generation is not a determining factor in this case, either.

On annual frequency, generation of 225 m^3 of liquid waste is anticipated, a greater part of which (200 m^3/year) is evaporation residue (concentrate). However, as liquid waste is classified as well, the evaporator acidifying solutions, ion exchange resins (5 m^3/year without the transport water), sludge (20 m^3/year) and decontamination solutions. Decontamination solutions are generated periodically. Thus, the annual amount of generation has not been determined.

The estimates of the amount of excess radioactive waste to be generated until the end of the currently licensed 50-year operational lifetime and in course of the additional 20-year operating lifetime extension period – based on data for 2023 – are presented in *Table 5.6.1.2-1*. According to the estimate, the volume of operational radioactive waste to be disposed of after conditioning will increase by nearly 3,000 m^3, from ≈14,000 m^3 to ≈17,000 m^3.

The collection, classification, treatment and preparation for transport and final disposal of operational waste generated in course of SSLE will be carried out in accordance with the procedures in force of the NPP and the existing treatment processes, as presented in *Chapter 2.2.1.1*.

Table 5.6.1.2-1. Inventory of low- and intermediate-level operational radioactive waste generated at the Paks NPP in course of the licensed 50-year operational lifetime and the planned 70-year of operational lifetime with the implementation of an additional 20-year operational lifetime extension

	Waste stream	Stored quantity (as of January 1, 2025) [m^3]	Annual generation [m^3]	Generated by the end of the 50 (30+20) years of operational lifetime	Generated by the end of the 70 (30+20+20) years of operational lifetime	Treatment	Radioactive waste to be disposed				
							Waste package	By the end of the 50 (30+20) years of operational lifetime		By the end of the 70 (30+20+20) years of operational lifetime	
								Quantity [m^3]	Volume [m^3]	Quantity [m^3]	Volume [m^3]
Solid	Compacted waste (placement in reinforced concrete container)	0	0	967	967	None	Reinforced concrete container	537	967	537	967
	Compacted non-historical waste disposed in barrels	0	55	603	969	None	Barrel	3 017	603	4 847	970
	Compacted non-historical waste in compact waste package	998		1 367	2 217	Packing into compact waste packages	Compact waste package	1 720	3 165	2 771	5 099
	Non compacted waste	828	33	1 160	1 853			1 450	2 668	2 316	4 261
	Soaked by diatomaceous earth- and dewatered sludge	150	3	181	254			226	416	316	581
	Co removal post-filter	67	14	283	443			367	675	553	1 018
	Large size waste	–	–	200	200	None	Container (4 m^3)	50	200	50	200
	Cs-column storage container	19	n/a	51	80	None	Container (1.7 m^3)	30	51	47	80

	Waste stream	Stored quantity (as of January 1, 2025) [m^3]	Annual generation [m^3]	Generated by the end of the 50 (30+20) years of operational lifetime	Generated by the end of the 70 (30+20+20) years of operational lifetime	Treatment	Radioactive waste to be disposed				
							Waste package	By the end of the 50 (30+20) years of operational lifetime		By the end of the 70 (30+20+20) years of operational lifetime	
								Quantity [m^3]	Volume [m^3]	Quantity [m^3]	Volume [m^3]
Liquid	Evaporation residue from normal operation	3 620	200	7 645	12 055	FHF technology	–	1 808 Appears partly in solid waste	3 327	857* Appears partly in solid waste	1 577*
	Evaporation residue from accident (including sludge)	2 787	n/a	2 907	2 815	Cementation into a compact waste package (1.6-1.8 times increase in volume)	In compact waste package as cement paste				
	Sedimentation sludge and evaporation residue sludge	470	20	948	1 348						
	Evaporator acidulant solution (including sludge)	159	0	159	159						
	Decontamination solution (including sludge)	538	0	538	543						
	Ion-exchanging resin	314	5	508	598	Cementation into container (3.8 times increase in volume)	Container (same as the compact waste package)	1 002	1 894	1 260	2 319
							Operations and accident:		*13 966*		*17 072*

* In course of period of the SSLE, generation of 450 barrels of waste can be anticipated annually, what is proportional to the previous generation rate.

The majority of liquid waste to be cemented is alpha-contaminated evaporation residues, decontamination solutions and evaporator acid solutions, the amount of which. However, does not increase proportionally throughout the period of the further extension of the operational lifetime (presumably it will not be generated over time). Although the amount of various sludge will increase proportionally. However it does not represent a decisive volume. The difference in the generation rate and amount of the two types of waste streams (barrel and liquid to be cemented) in course of period of further extension of the operational lifetime is the reason that several such compact waste packages may be produced that will also include waste in barrels. A significant part of the waste to be cemented was generated or is still being generated in course of the 50-year operational lifetime. As a result of this is that the number of compact waste packages changing disproportionately with the progress of time.

5.6.1.3. Final disposal the of radioactive waste

The final disposal of low and intermediate level radioactive waste from the Paks NPP is granted in the National Radioactive Waste Repository (NRWR) (*Figure 5.6.1.3-1.*), which is an underground facility with storage vaults design, operated by the PURAM The final disposal of radioactive waste takes place in storage chambers located at a depth of 200-250 m below the surface. In accordance with the original storage concept, the preparation of the waste packages (loading of the barrels into reinforced concrete containers and then filling the reinforced concrete containers with inactive concrete) took place in the NRWR until 2017. The storage chamber marked I-K1 of the NRWR (*Figure 5.6.1.3-1.*) was filled up in May 2017. In the future, the NRWR will receive compact waste packages made at the Paks NPP and ensure their disposal in further storage chambers.



Source: Webpage of PURAM (rhk.hu)

Figure 5.6.1.3-1. The above surface facilities of the National Radioactive Waste Repository (NRHT) in Bátaapáti and loading of the reinforced concrete containers into its I-K1 marked storage chamber

The full recipient capacity of the Bátaapáti NRWR with the storage chambers to be constructed according to the original design would provide sufficient area for the 50 (30+20) year operational lifetime of the NPP, as well as for the low and intermediate level radioactive waste generated in course of its decommissioning.

The final disposal of the low and intermediate-level solid radioactive waste generated in course of the SSLE of the Paks NPP can be ensured by a later expansion of the NRWR storage capacity.

In order to assure the final disposal of the high-level waste they are collected in containers and filled with concrete. Taking into account the rate of generation of the high-level radioactive waste, the final disposal should only be solved in the course of the decommissioning phase of the power plant, as stated in the technical design of the NPP.

High-level waste is collected in containers for final disposal and poured with concrete. Taking into account the rate of generation of high-level radioactive waste, final disposal should only be solved during the decommissioning phase of the power plant, as stipulated in the technical plan of the NPP.

According to broad international consensus, the final disposal of high-level waste can be safely solved in a deep-geological repository. This is a facility constructed at a several hundred metres' depth, which is protected from ground-surface effects and processes, and in which, in addition to man-made technical facilities, the stable geological environment also guarantees the long-term safety. There is also a common standpoint 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 the residues of the processed spent fuel.

In Hungary, the research program to identify a potential repository site was launched at the end of 1993, by the investigation of the Boda Claystone Formation in the tunnels opened from the Mecsek uranium mine. The research for the final disposal of high-level waste, is in progress even nowadays. The PURAM has compiled the Boda Claystone Formation site investigation framework program in 2018, then updated it in 2022, which defines the tasks until 2036. According to the planned schedule, the repository facility will enter into operation in 2064.

5.6.2. Temporary storage of spent fuel assemblies

The spent fuel generated at the Paks NPP is stored for a longer period (currently 50 years) in an interim storage facility, in the SFISF, until a decision will be made on its reprocessing, or final disposal.

The design of the SFISF with its licensed modular vault dry storage (MVDS) technology, containing 33 vaults, can ensure the interim storage of the VVER-440 type spent fuel assemblies generated during the 50 (30+20) year operational lifetime of the Paks NPP.

The PURAM – in cooperation with MVM Paksi Atomerőmű Zrt. – has examined several alternatives concerning the SSLE of Paks NPP and the management of the spent fuel of the Paks II NPP, taking into account several aspects, including the commissioning of the new Paks units:

- The first alternative is to increase the storage capacity of the current MVDS technology of the SFISF for the further extension of the operational lifetime of the Paks NPP for the additional quantities of spent fuel. For this, it was assumed that a five-vault module would be installed on the western and eastern sides of the repository.
- The technical concept according to the second alternative considered a dual-purpose metal or concrete container for the further extension of the operational lifetime of the Paks NPP for the additional quantities of spent fuel.

Based on the results of the aforementioned studies, a decision was made in November 2025, that the temporary storage of spent fuel assemblies generated in course of the SSLE of Paks NPP, will be implemented by change-over to container-based technology.

From a technological point of view, this means that the preparation of the container as a storage unit for storage will take place in the NPP by means of systems of the power plant. After that, the container, in its closed and hermetically sealed condition, only needs to be transported to the SFISF storage area.

During the course of the examination of the possibilities of changing-over to the container technology, the possibility of using a new temporary storage technology of one of the potential suppliers arose, which is even more favourable than the container technologies examined so far in terms of the conditions of the Paks site. The basis of the technology – in terms of the preparation of spent fuel assemblies for storage – is identical to the container storage technologies investigated, with the difference that the temporary storage would not take place on the ground surface, in a hall, but in an underground built, ventilated concrete structure. The technology, developed more than 10 years ago and also having appropriate reference facilities, is the HI-STORM UMAX system of Holtec International, the description of which is given in *Chapter 2.2.2.4*.

From an environmental point of view, in the case of the transition to the new storage technology, the emissions related to the drying of spent fuel assemblies for storage will not be linked to the operations carried out in the SFISF, but to the operations carried out in the reactor hall of the NPP. These emissions are also significantly below the limit value in the case of the current SFISF technology, which is expected to be even more favourable, if even not significantly, in the case of the new technology. On the basis of the analyses performed in relation to the handling operations, it can be stated that the analyses and their findings regarding the radiation exposure of the population carried out within the framework of the EIA of the Paks NPP, in relation to the SSLE are also valid in the case of the application of the Holtec HI STORM UMAX technology. The detailed verification of all this, similarly to the considerations made in connection with fuel diversification, will be ensured by the preparation of the analyses necessary for the foundation of the nuclear safety licensing.

The planned technology will ensure the temporary storage of spent fuel generated in the course of the additional 20 years of operation on the present site of the SFISF, so the temporary storage will not require the occupation of additional land. Another advantage of the selected technology is that, in addition to keeping environmental impacts low, it can also be an alternative to the above-ground, storage hall container storage technology currently considered in the plans for the Paks II NPP.

6. Environmental consequences of abandonment (decommissioning of the NPP)

Decommissioning of a NPP is the final phase of the facility's lifetime, which begins with the termination of operational activities necessary for electricity generation. Decommissioning refers to the administrative and technical measures needed to be taken, in order to remove partial or complete regulatory oversight of the facility.

The purpose of decommissioning is to dismantle the designated part of the power plant, restore the site to its original condition, which includes the removal of radioactive contamination from the facility and the site (i.e. decontamination), the demolition of structures, dismantling of the installed infrastructure, disposal of the resulting waste, and the implementation of all verification activities that confirm that the decommissioning activities are carried out in accordance with the approved plans.

In accordance with standard practice for NPPs, the planning of the abandonment and decommissioning of the Paks NPP after the end of its operational lifetime has already begun as part of the operation. Based on the nuclear safety regulations regarding decommissioning, the possible solutions and effects of decommissioning are examined and evaluated during the operational period. These analyses are regularly updated during the operational life of the power plant and directly before the start of the decommissioning activities.

The planning, preparation and regulatory approval of a NPP's decommissioning is a process regulated in detail by law. Based on the Act CXVI of 1996 on atomic energy, the nuclear safety licensing and control of activities related to the decommissioning and dismantling of a NPP falls within the competence of the Hungarian Atomic Energy Authority (HAEA). Based on OAH Decree 1/2022. (IV. 29.) on nuclear safety requirements and related official activities – and also detailing the requirements for dismantling – a permit from HAEA is required for dismantling.

The licensee of the NPP prepares a so-called Initial Decommissioning Plan, which is regularly updated during the operational period and submitted to the HAEA for information purposes after each review. The decommissioning plan is reviewed in a 5-year cycle in order to take into account and properly monitor changes in the NPP. The review also includes an assessment of the environmental impacts based on the current version of the decommissioning plan. At the time of preparation of the EIA, the 2021 version is in effect, which does not yet take into account the planned additional 20-year operating lifetime extension. The next review of the decommissioning plan will take place in the second half of 2026. After obtaining the permits for the subsequent extension of the NPP's operating lifetime, the upcoming review of the decommissioning plan will take into account the additional 20-year operating lifetime.

Based on Act CXVI of 1996, the body designated by the Government, the Public Limited Company for Radioactive Waste Management (PURAM), ensures the final disposal of radioactive waste, the temporary storage of spent fuel, the completion of the nuclear fuel cycle, as well as performing the tasks related to the decommissioning of nuclear facilities. The preparation and implementation of decommissioning is financed by the Central Nuclear Financial Fund in accordance with Section 62 of the aforementioned Act.

The abandonment (decommissioning) of the NPP is an activity subject to an environmental impact assessment, pursuant to Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures. This is also stated in Section II. 6.5. of the consolidated environmental license of the Paks NPP, reference number 391-18/2017: *"The termination of operations (decommissioning of the power plant) is an activity subject to an independent impact assessment"*. Accordingly, an EIA must be prepared for the decommissioning activity and an environmental license must be obtained from the competent environmental protection authority. A detailed analysis of the decommissioning activities and their anticipated impacts, as well as the identification of the necessary environmental protection measures – including the method of post-decommissioning environmental monitoring – will be the subject of an independent EIA for the decommissioning of the NPP, which must be prepared and approved by the organization responsible for decommissioning at the end of the extended operating lifetime, prior to the decommissioning process.

6.1. Regulatory requirements relevant to decommissioning

The most important nuclear and environmental regulations for the licensing, regulatory oversight and the implementation of NPP decommissioning are as follows:

- Act CXVI of 1996 on atomic energy:
  - The licensing and oversight of nuclear safety for activities related to the decommissioning and dismantling of the NPP fall within the jurisdiction of the HAEA.
  - The tasks related to decommissioning are financed from a separate public fund, the Central Nuclear Financial Fund, and the NPP is obliged to cover the costs of the decommissioning by making payments into the fund.
  - PURAM is required to carry out the tasks related to decommissioning as designated by the Government.
- OAH Decree 1/2022. (IV. 29.) on the nuclear safety requirements of nuclear facilities and on related regulatory activities and its Annexes 1-10 are the Nuclear Safety Code (NSC):
  - A permit from the HAEA is required for the dismantling of the NPP (decommissioning permit).
  - The licensee of the NPP shall submit the Initial Decommissioning Plan after each update to the HAEA for information purposes during the operating period.
  - The nuclear safety requirements for the planning and implementation of the decommissioning of a NPP are defined in Volume 8 of the NSC.
- OAH Decree 2/2022. (IV. 29.):
  - The regulation sets out general radiation protection requirements that must be applied in the case of activities related to the use of nuclear energy or where ionizing radiation is present.
- Ministerial Decree 15/2001. (VI. 6.) KöM on radioactive discharges to the atmosphere and into waters during the use of atomic energy and on monitoring of the discharge:
  - The scope of the regulation also covers decommissioning activities related to the release of radioactive materials into the air and water, as well as the control of radioactive contamination of the air and aquatic environment.
- LIII of 1995 law on the general rules for the protection of the environment:
  - Based on Section 68 (1) and (2) of the Act, the decommissioning activity of the Paks NPP is clearly qualified as an activity with a significant impact on the environment and is therefore subject to an EIA.
  - Based on Section 69 (1), the results of the EIA must be presented in an EIAR.
- Act CLXXXV of 2012 on waste:
  - Given the large amount of inactive waste generated during decommissioning, compliance with legal requirements is mandatory, and during decommissioning, efforts must be made to apply the most efficient and environmentally friendly waste management solutions that are feasible within the given technical and economic requirements.
- Government Decree 314/2005. (XII. 25.) on environmental impact assessment and integrated environmental use permitting procedures:
  - The scope of activities subject to an environmental impact assessment is defined in Annex 1 of the decree (the abandonment of NPPs and nuclear reactors (without size restrictions) is listed in point 31).
  - The decree regulates in detail the process and content of the EIA procedure, as well as the execution of the international EIA procedure, the scope of documentation to be submitted and its content.
  - The general content requirements of the EIA are defined in Annex 6 of the Government Decree 314/2005. (XII. 25.).

On December 13, 2011, the European Parliament and the Council adopted Directive 2011/92/EU, which regulates the assessment of the environmental impact of certain public and private projects. This directive applies to the EIA of projects that are likely to have a significant impact on the

environment. Its purpose is to ensure that Member States take all necessary measures to make it mandatory to obtain a permit and to carry out an EIA for projects that are likely to have a significant impact on the environment due to, among other things, their nature, size, or location, prior to the granting of such a permit.

Article 4 (1) of the Directive refers to Annex I, which lists the projects for which an assessment must be carried out. Annex I, point 2 b), refers to the decommissioning of NPPs: *"NPPs and other nuclear reactors, including the dismantling and decommissioning of such power plants and reactors"*. The Directive also provides guidance on the content and scope of the impact assessment.

6.2. Implementation and activities of decommissioning

Based on the Initial Decommissioning Plan valid at the time of preparation of the EIA, which was revised in 2021, the currently accepted decommissioning strategy is the protected preservation of the primary circuit for 20 years. All four units of the Paks NPP will be decommissioned. The order of shutdowns is the same as the order of commissioning. The expected dates of shutdown of the units, taking into account the planned additional 20-year operating lifetime extension, are the following:

- Unit 1: December 31, 2052.
- Unit 2: December 31, 2054.
- Unit 3: December 31, 2056.
- Unit 4: December 31, 2057.

According to the Initial Decommissioning Plan, the decommissioning works can be divided into the following three main phases:

Phase 1: Preparation for protected preservation of the primary circuit.

Phase 2: 20-year protected preservation of the primary circuit.

Phase 3: Dismantling/demolition of primary circuit systems and buildings.

In terms of environmental impacts, the activities carried out during phases 1 and 3, are the most significant. The timeline of the decommissioning process and the typical activities to be carried out in each phase are shown in *Figure 6.2-1.*

The following typical activities are performed during the decommissioning phases:

- Phase 1: Preparation for protected preservation of the primary circuit:
  - zoning in buildings – minor decontamination of contaminated areas, redefinition of the radiological controlled area, reducing the number of entry points, etc.,
  - modification of systems necessary to maintain the protected preservation of the primary circuit,
  - modification of civil structures and systems to ensure the long-term safety of the protected preservation of the primary circuit.
- Phase 2: 20-year protected preservation of the primary circuit.
- Phase 3: Dismantling/demolition of primary circuit systems and buildings:
  - preparation for decommissioning,
  - decommissioning of slightly contaminated or inactive auxiliary systems,
  - decommissioning of primary circuit systems,
  - decommissioning of reactors,
  - decontamination and radiation protection monitoring of civil structures,
  - demolition of civil structures, decontamination of the site and handover.

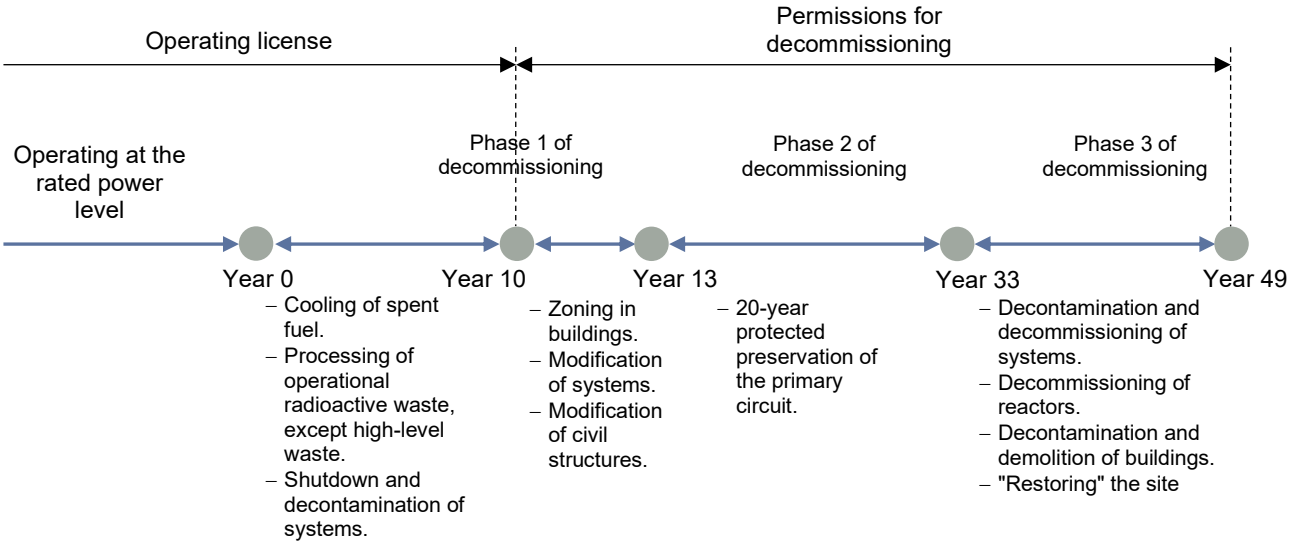


Figure 6.2-1. Time schedule for decommissioning the NPP assuming 20 years of protected preservation of the primary circuit

In phase 1, the radioactive and inactive materials generated will be treated in existing systems established for the management of operational radioactive waste. In phase 2, the waste generated will be minimized and collected, and treatment will only take place in phase 3. Within the scope of phase 3, waste management capacity will be built.

According to Parliament Resolution 21/2015. (V. 4.) OGY on the national policy on spent fuel and radioactive waste, licensees are obliged to ensure that the decommissioning plans of nuclear facilities follow the changes in nuclear safety regulatory requirements and technological developments by regularly reviewing and updating them as necessary. Accordingly, considerations regarding the further extension of the operating lifetime of Paks NPP will be taken into consideration during the next review of the Initial Decommissioning Plan and the decommissioning policy.

6.3. Overview of the expected environmental impacts of decommissioning

Based on the decommissioning plan, the most important work processes for the decommissioning of the NPP are the following:

- technical preparation (preparation for decommissioning, development of decommissioning infrastructure, procurement, draining of systems, waste disposal),
- dismantling of systems,
- demolition of buildings and civil structures,
- waste management activities (collection, selection, storage, packaging, delivery),
- radiological monitoring,
- decontamination of contaminated surfaces and equipment,
- transportation activities (to and from site),
- dismantling of decommissioning infrastructure, landscaping.

The decommissioning processes can be further broken down, based on which an environmental impact matrix can be prepared and the expected environmental impacts can be estimated. The identified environmental impacts can be assigned to the activities listed in detail in the impact matrix, which is useful for an overview of the impacts, but cannot be considered a comprehensive and complete systematization of the impacts, as the analysis of secondary and associated impacts requires further investigation. A matrix overview of the environmental impacts associated with the decommissioning of the NPP is shown in *Table 6.3-1.*

The potential impacts of decommissioning are shown below by environmental elements, or systems, with a brief description of each. For each impact, it is indicated whether the impact appears as a conventional, or radiological impact for the given environmental elements or

systems, which will be determined in detail within the scope of the EIA for decommissioning. The potential environmental impacts of decommissioning of the power plant can be summarized as follows:

- Air: Decommissioning includes the demolition of buildings, shredding of the resulting debris, dismantling of systems and equipment, etc. The activities associated with decommissioning assume the movement of large and heavy vehicles and machinery. Air quality is the primary factor affected by the decommissioning process, taking into account the meteorological characteristics of the region, as all such activities may cause the emission of radioactive and inactive gases, aerosols and dust. When dismantling equipment with higher level of radioactive contamination, the use of highly efficient mobile extraction and filtration equipment is assumed, as well as appropriately modified systems of the power plant in order to minimize the release of contaminated and uncontaminated aerosols. During the decommissioning period, conventional (non-radioactive) air pollutants are expected to enter the environment from two areas. On the one hand, equipment that was in operation during the operational period will continue to be in use. Such an example may be the emergency diesel generator operating as an emergency power source remaining in the plant. On the other hand, new sources of air pollution will come into operation. The most important of these are emissions from transport, emissions from the engines of various mobile equipment, dust pollution from the demolition of buildings and dust and combustion product emissions from on-site waste processing. Overall, both conventional and radiological effects are expected. Compliance with the relevant environmental limits and requirements can be ensured through the use of appropriate technology, which is becoming increasingly environmentally friendly due to the continuous advancement of the equipment used, and administrative regulations.
- Surface and groundwater: The impacts of the decommissioning process affect these environmental systems depending on the hydrological and hydrogeological characteristics of the site. During decommissioning, radioactive wastewaters are discharged from control tanks. The liquid radioactive waste category mainly includes solutions from pre-decommissioning and post-decommissioning decontamination and decontamination of building surfaces, as well as condensates and wash waters from waste processing systems. In terms of conventional emissions, in addition to municipal wastewater emissions, operational wastewater emissions are unlikely, at most, if necessary, cooling waters of some machines can be included here, which may represent a minimal load. With the termination of nuclear power generation, the thermal load on the Danube caused by the discharge of warmed cooling water will cease, which represents a positive change. Based on the above, possible contamination of surface and groundwater must be taken into account, which may be caused by the polluting components of the released and dissolved substances. The removal of man-made surfaces (demolition of roads and buildings) alters surface water runoff, the area’s drainage, and the infiltration of runoff into the groundwater. Overall, conventional and radiological impacts are expected, in which case compliance with the relevant environmental limits and requirements can be ensured by applying appropriate technology and administrative regulations, which are increasingly environmentally friendly due to the continuous development of the tools used.
- Noise: When considering the noise exposure of dismantling, the primary consideration should be given to the operating noise sources, the access routes and areas required for dismantling, and their distance from the objects to be protected. Noise sources include the machinery and equipment used in dismantling (trailers, excavators, crushers, shredders), freight vehicles moving within and outside the site (road, railway), and vehicles used to transport people participating in the dismantling work (road). Overall, a conventional impact is expected, in which case compliance with the relevant environmental protection limits and requirements can be ensured by applying appropriate technology and administrative regulations, which are increasingly environmentally friendly due to the continuous development of the equipment used.
- Land and soil: The significance of the impacts here varies depending on the chosen decommissioning strategy. The buildings will be demolished in accordance with the chosen

strategy. The controlled debris will then be removed. Changes to the land surface may be caused by levelling, compaction and removal of underground structures. The settling of contaminated particles released into the air during demolition may affect soil quality, although the resulting contaminated areas are expected to remain within the site. Overall, a conventional impact is expected, in which case compliance with the relevant environmental limits and requirements can be ensured by applying appropriate – increasingly environmentally friendly – technology and administrative regulations resulting from the continuous development of the tools used.

- Wildlife, ecosystems: The impacts on flora are caused by the appearance and settling of dust released during the works on the surrounding farmland and on the leaves of plants. The impacts on wildlife may be caused on the one hand by the increase in noise levels (regarding the habitat of certain species and their behaviour), on the other hand, changes in flora may also play a role as a secondary cause (e.g. in the event of the disappearance or appearance of plants serving as food, or due to changes in hiding places). The termination of thermal loading on the Danube also represents a positive change for wildlife. Overall, a conventional impact is expected, in which compliance with the relevant environmental limits and requirements can be ensured through the use of appropriate technology and administrative regulations, which are becoming increasingly environmentally friendly as a result of continuous improvements in the tools employed.
- Landscape (landscape character): Changes to the landscape that may occur during decommissioning are expected to result in positive changes, in line with the selected decommissioning strategy. The fact of decommissioning, demolition, and liquidation may influence recreational and vacation-related land use, tourism, the development of the tourism industry, the availability of the area for industrial purposes, changes in the use of industrial land, unused land, and rights of way. Of course, all of this depends on the operating lifetime of other facilities at the site and the schedule for the planned decommissioning. Overall, a conventional impact is expected, in which compliance with the relevant environmental limits and requirements can be ensured through the use of appropriate technology and administrative regulations, which are becoming increasingly environmentally friendly due to the continuous development of the tools used.
- Waste generation: Waste management encompasses all activities related to the sorting, cutting, decontamination, processing, classification, packaging, transportation, temporary storage and transport to final disposal sites of waste generated during decommissioning.

  During decommissioning activities, some of the materials generated can be released from regulatory control and subsequently reused, or treated as non-radioactive waste. Inactive waste from the dismantling of systems and the demolition of buildings/civil structures typically includes: concrete, reinforced concrete, stainless and other steel, masonry, non-ferrous metal.

  Radioactive waste generated during decommissioning is the material whose radiological properties do not allow for release from regulatory control, or release into the environment. Radioactively contaminated waste may include the reactor vessel and its internal structural elements, certain elements of systems, layers removed from the surface of chimneys, and contaminated concrete. The ultimate goal of radioactive waste is to meet the requirements for safe transportation, storage, and final disposal. There are many methods for managing radioactive waste generated during the decommissioning of NPPs. The selection of the most appropriate technology in a given situation is preceded by a detailed analysis. The waste management, conditioning, and disposal solutions included in the current plan are based on the best current knowledge, but by the time the NPP is decommissioned, the experience, knowledge, and technology that facilitates the performance of waste management operations will have multiplied worldwide. The review of tools and procedures used in waste management must be based on the best available experience at all times.

  The final step in waste management on site is the transport of waste to final a disposal site. Depending on their activity, the removal can take place separately and to different locations:
  - Inactive waste storage facilities, where waste that was not originally contaminated or has been decontaminated and released from regulatory control can be transported:

- waste recovery plants, where the delivered waste is used without transformation, such as broken and sorted concrete and brick rubble (after on-site processing),
- waste management companies, where valuable materials are produced by modifying and transforming waste, such as foundries,
- communal waste landfill where non-hazardous, but non-recyclable waste can be disposed of,
- hazardous waste landfill, for waste classified as hazardous waste according to Ministerial Decree 72/2013. (VIII. 27.) VM concerning the list of wastes.

– Radioactive waste storage facilities:
  - the underground storage, where low- and medium-level radioactive waste placed in containers and conditioned into its final form is transported,
  - deep geological storage, where high-level radioactive waste, which is unsuitable for placement in underground storage, is transported, placed in a container and conditioned to its final form.

Regarding the social, sociological and economic impacts of decommissioning, in addition to the fact that only conventional impacts can be interpreted, a key determining factor is that the impacts resulting from the decommissioning of the four units of the Paks NPP cannot be separated from the operation and decommissioning of the two neighbouring nuclear facilities, the Spent Fuel Interim Storage Facility, and the two new NPP units under construction. All of these will be examined, determined and evaluated in detail as part of the development of the decommissioning plans for the facilities. Given that the further extension of the operating lifetime of the Paks NPP is planned using existing plant technology and the existing buildings and civil structures, the continued operation is not expected to affect the environmental impacts of decommissioning as described above.

The Initial Decommissioning Plan also examines potential emergency events and accidents. The following events have been identified as cover events:

– leakage of liquid radioactive medium from parts of the primary circuit during decontamination,
– aerosol formation during dismantling of the primary circuit due to unprofessional work,
– incidents resulting from equipment being dropped.

The results of the investigations of the benchmark events show that the maximum radioactive releases into the environment during such events remain several orders of magnitude below the annual limit.

A monitoring system will be used to monitor and assess the impacts of expected release during decommissioning. The monitoring of environmental release (air, soil, water, noise emissions) will be planned based on the knowledge of the individual work phases, the technologies and equipment to be used. At this point, it will be determined where it is necessary to set up measurement points within or even outside the site, and what inspection methods and instruments will be used to perform the monitoring.

Based on the results of the environmental assessments carried out as part of the preparation and regular updates of the decommissioning plan, it can be concluded that the decommissioning of the Paks NPP will be feasible in compliance with the environmental protection regulations in effect at the time of decommissioning.

The decommissioning of the four units of the Paks NPP, the partial, or complete termination of the regulatory supervision of the facility will be implemented taking into account the decommissioning strategy and plans for the operating Spent Fuel Interim Storage Facility (SFISF) and the new power plant units under construction. The specific planning and implementation of the decommissioning of the four units, the assessment of their environmental impacts, and the determination of the methods for post-decommissioning environmental monitoring, and the nuclear safety and environmental regulatory licensing of the activities are ensured as part of the processes described above.

Table 6.3-1. Matrix representation of the identification of environmental impacts related to the decommissioning of the NPP1

Decommissioning project activities	Environmental elements/systems likely to be affected									
	Natural environmental elements/systems					Social, sociological, economic systems				
	Air	Water	Land area and soil	Flora and fauna	Landscape	Land use, area utilization	Culture	Infrastructure	Human aspects	Population and economy
Establish temporary storage locations and install or create devices					C	C		C		
Draining power plant systems		C/R	C/R							
Processing and packaging of industrial fluids									C/R	C/R
Transportation of industrial fluids	C							C	C	C
Decontamination	C/R	C/R							C/R	
Inspection and maintenance of systems, equipment, facilities								C/R	C/R	
Deployment of heavy equipment	C		C					C	C	
Installation and maintenance of the infrastructure necessary to support the workforce			C		C		C	C	C	C
Maintaining working conditions								C	C	C
Workplace services								C		C
Installation and de-installation of decommissioning infrastructure	C		C	C		C		C		C
Dismantling and transportation of contaminated main equipment	C/R			C				C	C	
Dismantling and decommissioning of inactive power plant systems and equipment	C	C	C							
Removal of contaminated building structures	C/R		C/R			C/R				
Removal of contamination within the building caused by leaks	R								R	
Removal of contaminated underground power plant systems	R	R	R						R	
Extraction of contaminated civil structures and soil due to leaks	R	R	R		R	R			R	
Selective removal of conventional waste						C		C	C	
Selective removal of radioactive waste						R		R	R	

Decommissioning project activities	Environmental elements/systems likely to be affected									
	Natural environmental elements/systems					Social, sociological, economic systems				
	Air	Water	Land area and soil	Flora and fauna	Landscape	Land use, area utilization	Culture	Infrastructure	Human aspects	Population and economy
Processing of conventional waste	C	C	C		C	C		C	C	C
Processing of radioactive waste								C/R	C/R	C
On-site storage of conventional waste			C					C		
On-site storage of radioactive waste						C		C	R	
Use of inactive construction debris			C		C	C		C		C
Conventional waste transportation	C		C	C				C	C	C
Radioactive waste transportation	C			C/R				C	C	
Handling of hazardous materials								C	C	
Accident / emergency event – fires	C/R				C				C/R	C
Accident / emergency event – leaks, washouts	C/R	C/R	C/R						C/R	
Accident / emergency event – maintenance errors							C		C	
Accident / emergency event – structural damage caused by external factors	C/R	C/R	C/R			C		C	C/R	C

Legend: C – conventional environmental impacts.
R – radiological impacts.

7. Summary of environmental impacts and their territorial extent

7.1. Summary assessment from the perspective of environmental receptors

The assessment of actual environmental stressors associated with the further operation of the NPP, as well as with accidents and emergency events, and the resulting impacts, was based on the potential stressors and assumed impacts considered in *Chapter 3.1.*

The basic assumption of the examination of the expected environmental impacts related to the further extension of the operating period, is that the current environmental impacts and impact processes related to the power plant will continue to be decisive in the future. Therefore, the currently existing impact factors must continue to be taken into account. However, their “operational” period will be extended by the 20-year period of further operation.

During the impact assessment, the individual environmental impacts were classified according to the criteria described in *Chapter 1.6.3.* The impact area was defined as the area where the given impact can be detected or estimated.

The estimated impact areas of environmental impacts arising from activities necessary for the preparation of the further operational life extension of the Paks NPP, as well as those resulting from continued operation and associated with potential accidents and emergency events, are presented in tabular form. *Tables 7.1-1. - 7.1-3.* give the evaluation and geographical extent of the environmental impacts, broken down by the impact factors for individual environmental elements and systems, for the preparation and further operation phase of the SSLE, for normal operation and in the event of accident or emergency event.

Data reflecting the environmental impacts observed during the operation of the Paks NPP to date, and taking into account the expected impacts of the modifications planned as part of the preparation of the SSLE, it can be stated that no environmental, nature, or landscape protection reasons can be identified that would make the planned further extension of the NPP’s operating life impossible.

Table 7.1-1. Extent of the impact areas of the environmental impacts resulting from the preparation of the SSLE of the Paks NPP1

Impact factor / activity	Impacts / impact processes	Environmental receptor	Impact area	Nature of impact
Impacts on air quality				
Air pollutant emissions from construction work	Change in air quality	Ambient air	Within a radius of 1100 m from the centre of the emissions (Unified national projection Y: 635873.2 m; X: 136988.9 m): in the installation and operational area, and in the off-site area.	Change in condition: burdensome Duration: medium-term Significance: medium importance
Impacts on surface waters				
Construction activities affecting the Danube riverbed	Water quality change	Aquatic communities	Riverbed area affected by construction works	Change in condition: tolerable Duration: short term Significance: low importance
Impacts on geological structures and groundwater				
Site Filling	Physical change of geological medium	Geological medium and groundwater	The area affected by the filling is considered the impact area.	Change in condition: neutral Duration: long-term persistent Significance: low importance
Dredging	Physical change of geological medium	Geological medium	The area affected by dredging and placement of riverbed material is considered an impact area.	Change in condition: neutral Duration: long-term Significance: low importance
Road construction	Physical change of geological medium	Geological medium	The area affected by the construction and its 5-meter buffer zone can be considered the impact area.	Change in condition: neutral Duration: long-term Significance: low importance
Impacts on wildlife and ecosystems				
Construction of the facility	Changes in living conditions	Wildlife, ecosystems	The area affected by construction work and its immediate surroundings	Change in condition: burdensome Duration: short term Significance: medium importance

Impact factor / activity	Impacts / impact processes	Environmental receptor	Impact area	Nature of impact
Impacts on landscape and land use				
The appearance of the facility (buildings, structures)	Restrictions on land use, landscape disturbance	Surrounding population	The area affected by construction work and its immediate surroundings	Change in condition: tolerable Duration: short term Significance: low importance
Impacts on the urban environment				
The appearance of the facility (buildings, structures)	The effects on the functioning of settlements	Settlement, surrounding population	The area affected by the construction work and the transportation route, as well as its immediate surroundings	Change in condition: burdensome Duration: short term persistent Significance: low importance
Waste generation and management				
Generation, transportation and loading of non-hazardous and hazardous waste within the construction area	Land use	Soil	Within the boundaries of the property affected by the construction work	Change in condition: tolerable Duration: Medium-term Significance: low importance
Impacts on noise and vibration conditions				
Noise emissions from construction work, noise emissions from related road transport	Disturbance, deterioration in quality of life	Surrounding population, wildlife	The area within a radius of approximately 400-600 meters surrounding the construction site	Change in condition: neutral Duration: short term Significance: low importance

Table 7.1-2. Extent of the areas affected by the environmental impacts resulting from the SSLE of the Paks NPP under normal operating conditions

Impact factor / activity	Impacts / impact processes	Environmental receptor	Impact area	Nature of impact
Radiological impacts				
Controlled (airborne and liquid) radionuclide releases	Radiation exposure of the population	Representative person	Paks NPP safety zone	Change in condition: neutral Duration: long-term Significance: low importance
	Radiation exposure of wildlife	Representative organism	None	Change in condition: neutral Duration: long-term Significance: low importance
Conventional impacts				
Impacts on air quality				
Air pollutant emissions from the operation of point sources of air pollution (diesel generators)	Change in air quality	Ambient air	Within a 690-meter radius of the emission points (EOV Y 634982.6 m; X 136753.0 m), the site and areas outside the site	Change in condition: burdensome Duration: short term Significance: medium importance
Air pollutant emissions from related road transportation	Change in air quality	Ambient air	Within 30 meters of the edge of the roadway along the southern access road to the Paks NPP, within 20 meters of the edge of the roadway along the section between the southern access road of Main Road No. 6 and the Paks-Kölesd Road intersection.	Change in condition: neutral Duration: long-term Significance: low importance
Impacts on the weather and climate				
Rise in air temperature due to urbanization	Impacts on climatic factors (urban impact)	Atmosphere	The boundary of the operational area of Paks NPP	Change in condition: neutral Duration: long-term Significance: low importance
Discharge of warmed cooling water into the Danube	Changes in the water temperature of the Danube	Danube, atmosphere	None	Change in condition: neutral Duration: Long-term persistent Significance: low importance

Impact factor / activity	Impacts / impact processes	Environmental receptor	Impact area	Nature of impact
Vapour emission from cooling cells of a peak cooling system	Impacts on climatic factors	Atmosphere	None	Change in condition: neutral Duration: short term Significance: low importance
Impacts on surface waters				
Discharge of treated industrial, municipal wastewater and rainwater	Changes in the chemical characteristics of waters discharged into the Danube via the discharge water channel	Danube River	None	Change in condition: neutral Duration: long-term Significance: low importance
	Water quality change	Aquatic communities	None	Change in condition: neutral Duration: long-term Significance: low importance
Discharge of warmed cooling water into the Danube	Changes in the Danube river's habitat conditions (changes in the riverbed, changes in flow conditions), changes in community structure	Aquatic communities	17.3 km downstream from the discharge point	Change in condition: burdensome Duration: long-term Significance: high importance
Disposal of dredged material into the Danube from the cold-water channel	Changes in the habitat conditions of the Danube (changes in the riverbed) Change in water quality of the Danube (increase in suspended solids, potential heavy metal load) Changes to the structure of the aquatic community	Aquatic communities	In the downstream direction of the Danube to the Large Groyne, to the lower section of the Uszód tributary during the period of disposal	Change in condition: burdensome Duration: long-term Significance: high importance

Impact factor / activity	Impacts / impact processes	Environmental receptor	Impact area	Nature of impact
Impacts on groundwater				
Discharge of warmed cooling water into the Danube	Increase in groundwater temperature	Gerjen North Long-Term Water base Foktő-Baráka active water base Shallow porous groundwater body	None	Change in condition: neutral Duration: long-term Significance: low importance
	Decline in water levels due to drinking water production	Csámpa-puszta water base Porous groundwater body	None	Change in condition: neutral Duration: long-term Significance: low importance
	Increase in groundwater temperature	Gerjen North Long-Term Water base Foktő-Baráka active water base Shallow porous groundwater body	None	Change in condition: neutral Duration: long-term Significance: low importance
Impacts on wildlife and ecosystems				
The existence and operation of the facility (including the impact factors related to other environmental elements)	Changes in living conditions	Wildlife, ecosystems	Area within a radius of 2.8-3 kilometre around the site	Change in condition: neutral Duration: long-term Significance: low importance
Light emission (area lighting)	Changes in living conditions of nocturnal species	Wildlife, ecosystems	None	Change in condition: tolerable Duration: long-term Significance: low importance
Impacts on landscape and land use				
The existence of the facility (buildings, civil structures)	Restrictions on land use, landscape disturbance	Surrounding population	Area within a radius of 3-8 kilometre around the site	Change in condition: tolerable Duration: long-term Significance: low importance

Impact factor / activity	Impacts / impact processes	Environmental receptor	Impact area	Nature of impact
Impacts on the urban environment				
The existence and operation of the facility (buildings, civil structures)	Impacts on the operation and development of a settlement	Settlement, surrounding population	Inner parts of Paks town (contiguous, urban, industrial areas)	Change in condition: neutral Duration: long-term Significance: low importance
Waste generation and management				
Generation, on-site transportation and loading of non-hazardous and hazardous waste	Land use	Soil	The boundary of the operational area of Paks NPP (location of waste collection sites, storage facilities, immediate surroundings)	Change in condition: tolerable Duration: long-term Significance: low importance
Impacts on noise and vibration conditions				
Operating noise emissions,	Disturbance, deterioration in quality of life	Surrounding population, wildlife	The impact area is formed within a circle with a radius of ~2.3 kilometre, cantered east-northeast of the centre of the Paks NPP (EOV Y: 636453 m, X: 136977 m)	Change in condition: burdensome in Uszód, burdensome within the operating area, neutral in other protected areas Duration: long-term Significance: medium importance
Noise emissions from related road transportation	Disturbance, deterioration in quality of life	Surrounding population, wildlife	Along the Main Road No. 6, on the approximately 3 kilometres long section between the southern residential areas of Paks and the residential area of Csámpa, in the 50-400 meters strip along the road	Change in condition: overall neutral, initially tolerable along the Paks-Csámpa road, neutral elsewhere Duration: long-term Significance: low importance

Table 7.1-3. Extent of the areas affected by the environmental impacts resulting from the SSLE of the Paks NPP under design basis accident / emergency event

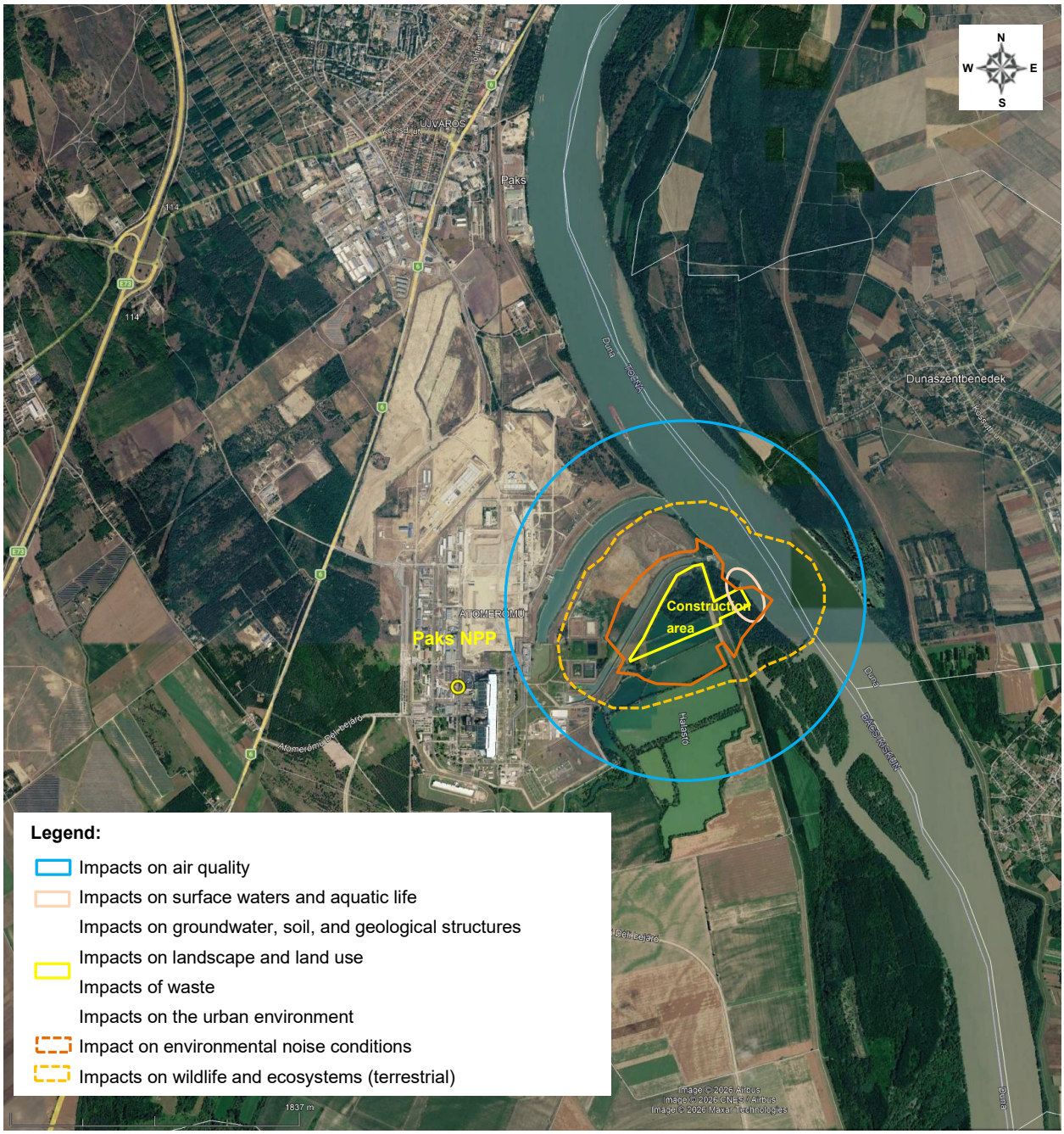
Impact factor / activity	Direct impact / impact processes	Environmental receptor	Impact area	Nature of direct impact
Radiological impacts				
Controlled (airborne and liquid) radionuclide releases	Radiation exposure of the population	Representative person	A circle with a 6-kilometre radius cantered on the emission point	Change in condition: tolerable Duration: short term Significance: medium importance
Conventional impacts				
Impacts on air quality				
Air pollutant emissions in case of a “black-out”, when several diesel generators operate simultaneously	Change in air quality	Ambient air	Within a radius of 1600 m from the centre of the emissions (EOV Y: 634962.6 m; X: 136625.3 m): in the on-site and in the off-site area.	Change in condition: burdensome Duration: short term Significance: medium importance
Impacts on surface waters				
Industrial, municipal wastewater and polluted rainwater release	Changes in the chemical characteristics of waters discharged into the Danube via the discharge water channel	Danube River	None	Change in condition: neutral Duration: short term Significance: low importance
	Water quality change	Aquatic communities	None	Change in condition: neutral Duration: short term Significance: low importance
Impacts on groundwater				
Contaminant release	Local pollution	Subsurface water environment (on-site)	Within the operating area of Paks NPP, locally	Change in condition: tolerable Duration: short term Significance: low importance

Impact factor / activity	Direct impact / impact processes	Environmental receptor	Impact area	Nature of direct impact
Impacts on soil and geological medium				
Contaminant, waste release	Local pollution	Soil, geological medium on the site	Within the operating area of Paks NPP, locally	Change in condition: tolerable Duration: short term Significance: low importance
Impacts on wildlife and ecosystems				
Contaminant release (into air, water, soil)	Damage to wildlife and their habitats	Wildlife, ecosystems	Area within a radius of 2.8-3 kilometre around the site	Change in condition: neutral Duration: short term Significance: low importance
Waste generation and management				
Generation of unplanned types/amounts of waste	Land use	Soil	Within the operating area of Paks NPP, locally	Change in condition: neutral Duration: short term Significance: low importance
Impacts on noise and vibration conditions				
Noise emissions in “black out” conditions (power plant noise sources and simultaneous operation of several diesel generators)	Disturbance, deterioration in quality of life	Surrounding population, wildlife	Area with a radius of 3-4.8 kilometre around the centre (major noise source, EOV Y: 635680 m, X: 136715 m)	Change in condition: burdensome Duration: short term Significance: low importance

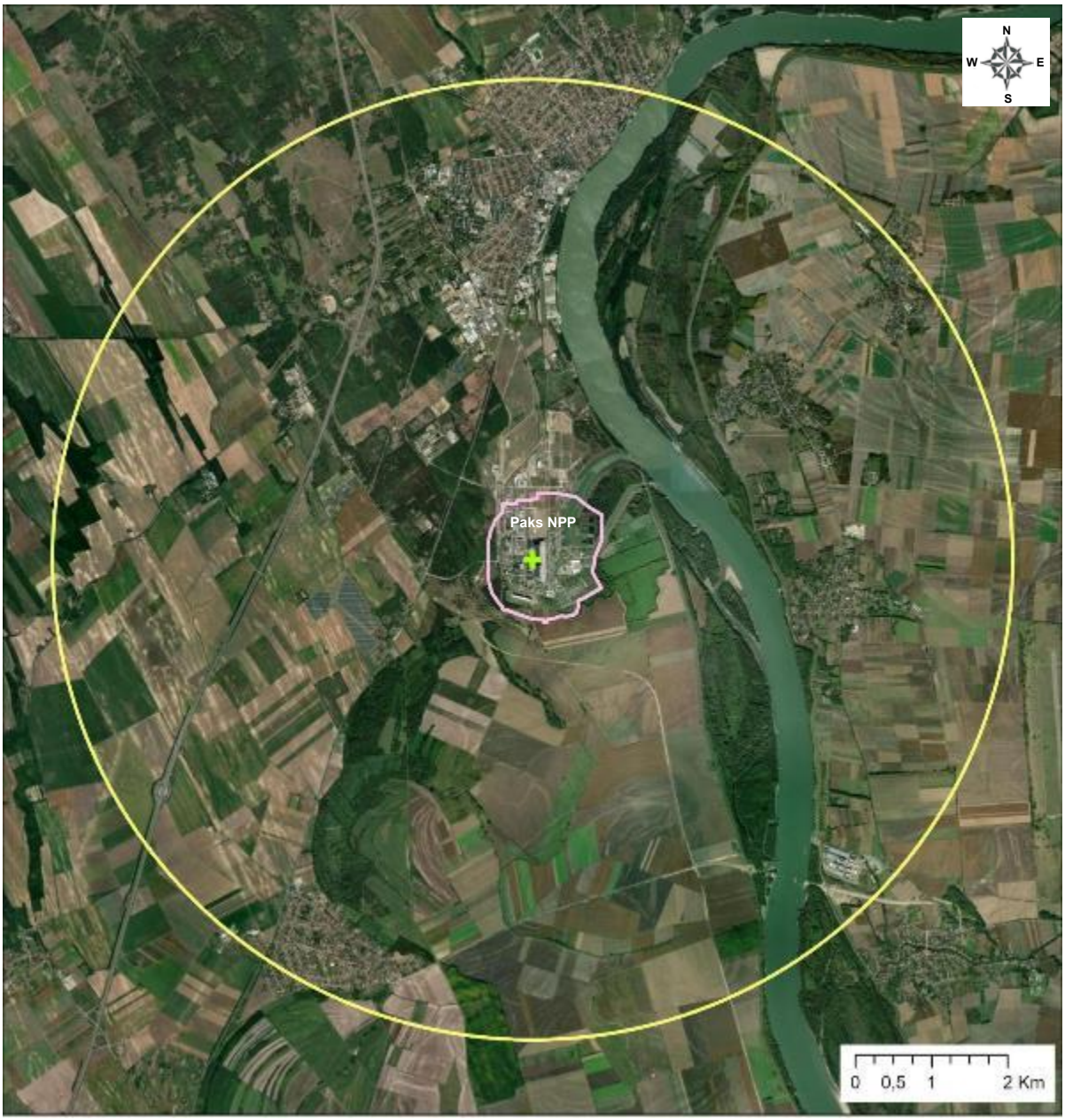
7.2. Territorial extent of impact processes

The impact areas for individual environmental elements and systems are shown in map form in *Figures 7.2-1. – 7.2-3. Figure 7.2-1.* shows the impact areas resulting from the preparation of the SSLE, while *Figures 7.2-2 – 7.2-4.* show the impact areas of environmental effects resulting from operations during the SSLE period. The total impact area, determined by aggregating the impact areas for individual environmental elements and systems, is shown in *Figure 7.2-5.*, which affects the settlements listed in *Table 7.2-1.*

The entire impact area of the environmental impacts associated with the planned further extension of the operating lifetime of the Paks NPP is the area within a radius of 6-17 kilometre of the site, which extends beyond the administrative boundaries of the town of Paks where the activity takes place to include the territories of 10 additional settlements.



7.2 Figure 7.2-1. Impact area of environmental impacts resulting from the preparation of the SSLE of the Paks NPP (conventional environmental impacts)1



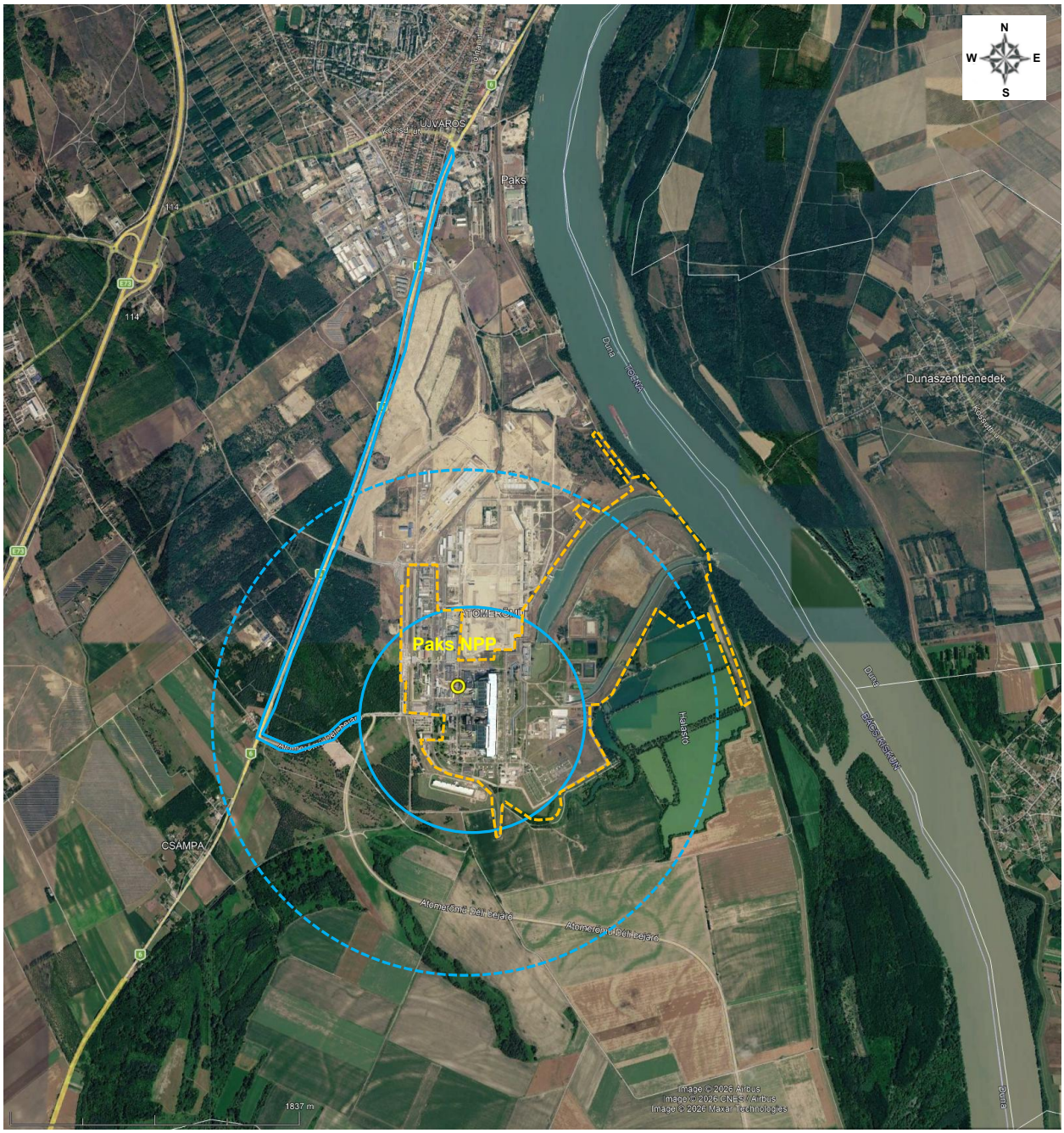
Legend:

- Paks NPP
- Radiological effects (normal operation: NPP safety zone)
- Radiological effects (accident: 6 km radius)

Figure 7.2-2. Estimated radiological impact area for the period of SSLE of the Paks NPP2



Figure 7.2-3. Estimated impact areas of conventional environmental impacts for the period of SSLE of the Paks NPP (surface waters, landscape, settlement environment, wildlife, noise emissions)3



Legend:

- Impacts on air quality (normal operation)
- Impacts on air quality (emergency event)
- Impacts on groundwater, soil, geological structures (emergency event)
- Meteorological and climatic impacts (normal operation)
- Impacts of non-radioactive waste (normal operation and emergency event)

7.2 Figure 7.2-4. Impact areas of conventional environmental impacts estimated for the period of SSLE of the Paks NPP (impacts on air quality, groundwater, soil, geological structures, meteorological and climate impacts, impacts of non-radioactive waste)4

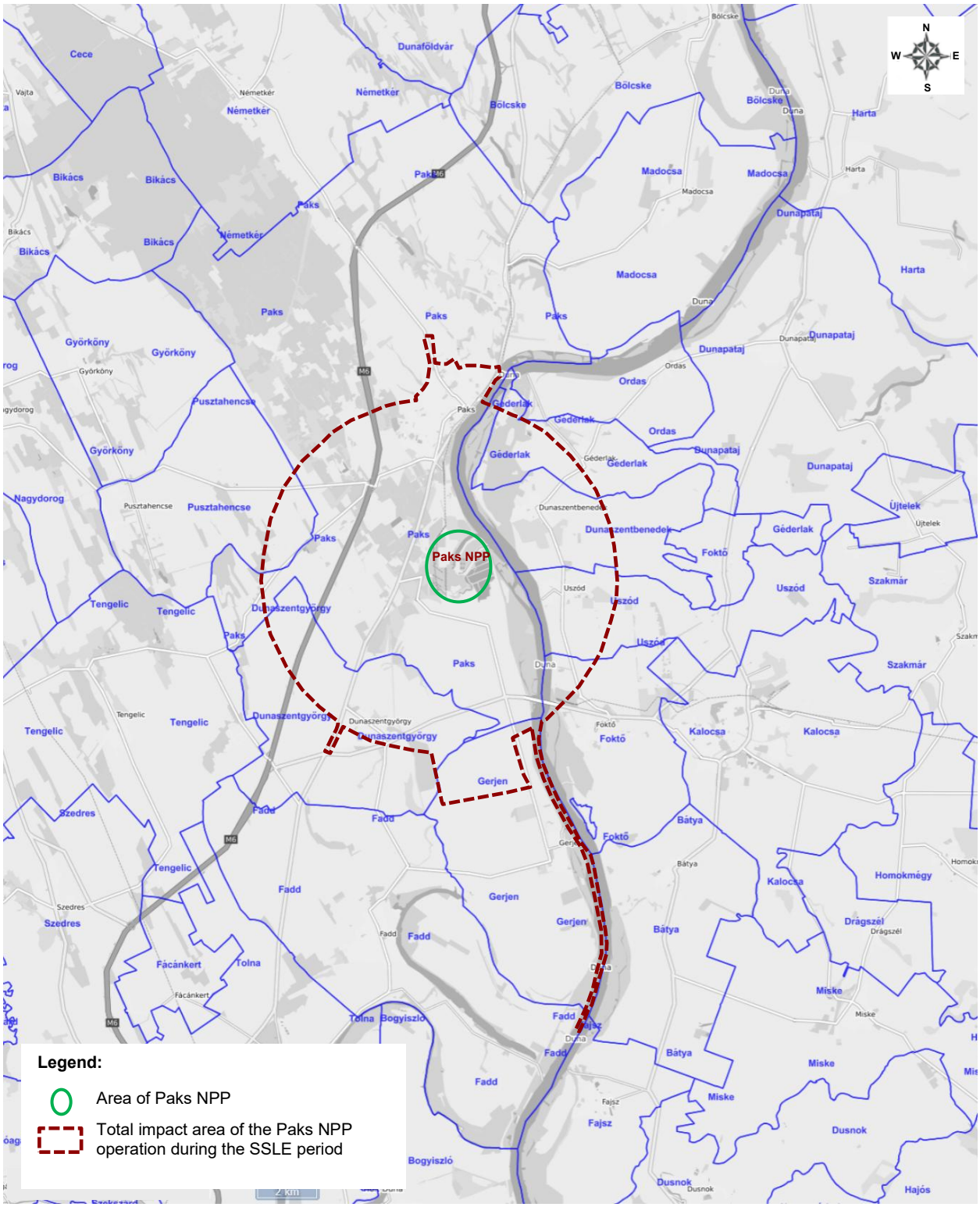


Figure 7.2-5. The total impact area of the environmental impacts resulting from the operation of the Paks NPP and the settlements affected by the impact area for the period of SSLE5

Table 7.2-1. Settlements affected by the total impact area of the expected environmental impacts resulting from the SSLE of the Paks NPP1

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

Source: Hungarian Central Statistical Office (HSCO) Census 2022

8. Assessment of potential transboundary environmental impacts

8.1. Aspects for the assessment of transboundary impacts

8.1.1. International and national requirements applicable to the impact assessment

The operation of NPPs falls within the scope of the Espoo Convention on environmental impact assessment in a transboundary context and Directive 2011/92/EU of the European Parliament and of the Council of 13th December 2011 on the assessment of the effects of certain public and private projects on the environment, as amended by Directive 2014/52/EU of 16th April 2014. The mandatory application of the Espoo Convention in Hungary is prescribed by Government Decree 148/1999. (X. 13.), promulgating the convention on environmental impact assessment in a transboundary context, signed in Espoo (Finland) on 26th February 1991.

A transboundary impact is defined as an impact whose impact area extends beyond a national border and causes significant permanent changes or long-term environmental deterioration. In the case of activities falling under the scope of the Convention, countries considering themselves affected may request the conduct of a transboundary environmental impact assessment procedure regardless of whether the impact area, according to the analyses performed, actually extends to their territory.

The detailed rules governing transboundary environmental impact assessment procedures required for activities covered by the Espoo Convention are established by Government Decree 314/2005. (XII. 25.) on environmental impact assessment and the integrated environmental use permitting procedures. Under the provisions of the decree, coordination of the transboundary environmental impact assessment procedure and communication with interested parties are the responsibility of the ministry headed by the minister responsible for environmental protection, which during the preliminary consultation process was the Ministry of Energy. Where significant transboundary environmental impacts are considered likely during the preliminary consultation process, the environmental authority informs the competent Ministry by forwarding the preliminary consultation documentation. The Ministry then notifies the foreign parties by transmitting the English-language version of the Preliminary Consultation Document. If a notified party indicates in its response, that it intends to participate in the EIA procedure, the procedure shall continue in accordance with the provisions of Government Decree 314/2005. (XII. 25.) governing transboundary environmental impact assessment procedures, taking into account the comments submitted by the affected party.

Upon commencement of the preliminary consultation process, the BCGO, acting as the competent environmental authority, informed the Ministry of Energy by submitting the application and the English-language version of the Preliminary Consultation Document. On 30th October 2024, taking into consideration the countries notified during the transboundary environmental impact assessment procedure for the Paks II NPP project, the Ministry of Energy notified 31 foreign parties, including Hungary's neighbouring countries, all Member States of the European Union, as well as the United Kingdom, Norway, and Switzerland.

Comments from the notified countries were received until 22nd January 2025, with feedback received from eight countries. 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 regarding the results of the EIA.

According to legal requirements the Ministry informs the foreign parties by transmitting the of the Public summary of the EIAR – prepared taking into account both the authority's opinion concluding the preliminary consultation and the comments received from foreign parties – translated into the language of the affected party or into English and the International chapter containing a review of the feedback received from foreign parties and the responses provided. The Ministry also initiates the consultation process based on these documents. Comments received during consultations with foreign parties, as well as comments submitted by the public of the affected party, are evaluated by the environmental authority with the involvement of the relevant competent authorities and are taken into account during decision-making within the environmental licensing procedure.

8.1.2. Environmental impacts, operating conditions, and events assessed from the perspective of potential transboundary impacts

As part of the investigations and analyses performed to support the EIAR for the proposed SSLE of the Paks NPP, the potential for transboundary environmental impacts and the significance of any potentially transboundary impacts were assessed for all identified conventional and radiological impacts, taking into account impact pathways and the sensitivity of affected areas. For each environmental impact factor, impacts potentially reaching national borders were evaluated with respect to air quality, surface water and groundwater, geological medium, flora and fauna and ecosystems, noise and vibration conditions, and environmental radiation conditions.

No significant transboundary impacts were identified under normal operating conditions of the Paks NPP, either in relation to conventional environmental impacts or radiological impacts resulting from gaseous and liquid discharges. Owing to the central location of the NPP within Hungary and the fact that the nearest national border is located more than 60 km away, no significant transboundary impacts were identified even for incidents or accidents deviating from normal operation.

In accordance with internationally accepted practice for impact assessments relating to nuclear facilities, the assessment of transboundary impacts included not only operational occurrences and design-basis accidents but also the analysis of events classified under nuclear safety requirements as design extension conditions, which, in Hungarian terminology, are categorized as complex or severe accidents. These analyses were also carried out as part of the transboundary impact assessment.

Compliance with very strict nuclear safety requirements for nuclear facilities, and thus NPPs, ensures that the probability of an accident occurring is extremely low. This is further reinforced by the fact that analyses of accidents that have occurred during the history of nuclear energy utilization have led to continuous improvements in both technology and the regulatory requirements governing the operation of nuclear facilities. As part of these improvements, numerous upgrades and safety enhancement measures have been implemented at the Paks NPP. As a result, the four-unit NPP commissioned in the 1980s continues to comply with modern nuclear safety requirements that are aligned with current international standards and regulations. The periodic modernization of regulatory requirements, together with the obligation to comply with them, ensures that the applicable safety requirements can continue to be met throughout the period of the proposed SSLE. Compliance with these requirements ensures that radiation exposure to the public remains below the prescribed criteria during normal operation as well as during anticipated operational occurrences and design basis accidents.

Unlike the requirements applicable to normal operation and design basis accidents, the regulatory provisions concerning design extension conditions and accident analyses do not specify dose limits. Instead, they require the implementation of protective measures, where necessary, to reduce radiation exposure to the public. Accordingly, the primary objective of the requirements relating to design extension conditions is to ensure that NPP operators and the organizations and authorities involved in emergency response are adequately prepared for the possible occurrence of low-probability events with potentially severe consequences.

In order to demonstrate the potential transboundary impacts of accidents, analyses were performed not only for normal operating conditions and design basis accidents, but also for design extension conditions that could result in significant radiological releases.

8.2. Conventional environmental impacts and impacts related to radiation exposure of wildlife

The analyses and impact assessments conducted in support of the EIAR for the SSLE of the Paks NPP did not identify any significant transboundary impacts associated with conventional environmental impacts and impacts related to radiation exposure of wildlife. The findings regarding the spatial extent of the impacts can be summarized as follows:

- **Impacts on air quality:** The areas affected by air pollutant emissions are limited to the NPP site and its immediate surroundings. Environmental impacts associated with transportation activities related to the operation of the NPP occur primarily along the immediate vicinity of Main Road No. 6 between Paks and Dunaszentgyörgy. The assessment results confirmed that no impacts approaching national borders can be identified, regardless of whether only the existing four units of the Paks NPP or the combined impacts of the existing units and the two new units of the Paks II NPP are considered.
- **Impacts on groundwater:** Based on monitoring data from bank-filtered water resources, the national groundwater monitoring network, and the on-site monitoring system of the Paks NPP, as well as on the results of regional and local hydrodynamic and heat transport models, it can be concluded that no transboundary environmental impacts can be identified. The impacts are local in nature both for the operation of the Paks NPP alone and for the combined operation of the Paks and the Paks II NPP.
- **Impacts on noise and vibration levels:** No transboundary environmental impacts are expected as a result of either the independent operation of the Paks NPP or the combined noise emissions of the Paks NPP and the Paks II NPP, since the boundary of the affected area is confined to a few kilometres around the NPP site.
- **Impacts on wildlife, and ecosystems:** As part of the assessment of impacts on wildlife and ecosystems, no adverse impacts could be demonstrated for the terrestrial habitats and biological communities examined within distances of 3 km and 10 km from the NPP. Consequently, no such impacts can be expected at greater distances, including beyond national borders.
- **Radiation exposure of wildlife:** Historical monitoring data reviewed as part of the assessment of radiation exposure to biota, together with the most recent measurement results, confirmed that only negligible activity concentrations can be detected even in the immediate vicinity of the NPP. Radioactivity released to the environment is subject to substantial dilution with increasing distance, therefore, radiation exposure of biota attributable to the NPP becomes even more negligible at greater distances. Consequently, no transboundary impacts are expected with respect to radiation exposure of biota, regardless of whether the Paks NPP operates stand-alone or together with the six-unit configuration comprising the Paks and the Paks II NPP.

8.3. Impacts of the expected Danube heat load during the period of the SSLE

The quantification of potential transboundary impacts was carried out using a multi-stage modelling methodology consisting of interconnected models, which enabled not only the assessment of current conditions but also the projection of future scenarios. As part of the investigations, projections were prepared for the entire Danube catchment based on two climate scenarios (RCP4.5 and RCP8.5). For each scenario, the results of fourteen relevant global and regional climate models were considered, allowing future meteorological conditions to be estimated through the combined evaluation of multiple climate models.

Building upon the climate model outputs, a catchment-scale hydrological model was developed for the entire Danube river system. Calibration and validation of the model were performed using approximately 30 years of international hydrological data, with calibration carried out separately for individual sub-catchments. This ensured that the simulations reliably reflected the hydrological characteristics of the Danube. The model was used to forecast how climate change may affect the river discharge of the Danube at the Paks cross-section. The results of the hydrological calculations served as the basis for subsequent investigations, particularly for water temperature and thermal load modelling.

Considering river discharge data and meteorological conditions, projections of future Danube water temperatures were also developed. For this purpose, a temperature model calibrated using several decades of measured data was applied. Based on the outputs of the hydrological and temperature models, hydrologically representative conditions of particular importance for both the

operation of the power plants and the receiving river were identified. These included average-flow conditions and biologically critical low-flow conditions. Detailed three-dimensional hydrodynamic and thermodynamic modelling was then used to determine the Danube water temperatures under which the cooling water discharges of the power plants would not yet require output restrictions due to exceedance of regulatory temperature limits.

For the detailed assessment of transboundary impacts, a depth-averaged two-dimensional (2D) hydrodynamic model was developed for the relevant section of the Danube. Calibration of the hydrodynamic model was performed using water level measurements for both low-flow and average-flow conditions. Remote sensing-derived water temperature data were also incorporated into the modelling of mixing and heat transport processes. This enabled the model to realistically describe the propagation of the thermal plume and the spatial distribution of water temperature.

The model was used not only to assess current hydrological and temperature conditions, but also to simulate future scenarios. These simulations incorporated the effects of climate change, including the projected reduction of low-flow discharges from approximately 910 m^3/s at present to around 790 m^3/s. In addition, the impacts associated with the commissioning of the Paks II NPP were specifically assessed, representing the scenario in which the Paks and the Paks II NPP operate simultaneously.

The modelling also accounted for heat exchange between the water surface and the atmosphere, a process that becomes particularly significant under elevated water temperature conditions. This mechanism results in gradual cooling of the river water downstream, thereby mitigating the effects of the thermal plume.

The two-dimensional hydrodynamic model was further used to investigate the longitudinal propagation of the thermal plume generated by the discharge of warmed cooling water. The calculations indicated that transverse mixing of the heated water becomes nearly complete across the full river cross-section after approximately 70 river kilometres. Under current conditions, thermal discharges from Paks cause an increase in water temperature at the national border of approximately 0.4°C under average-flow conditions and approximately 0.9°C under low-flow conditions. In the future scenario involving the simultaneous operation of the existing Paks units and Paks II NPP, this effect may nearly double, reaching approximately 0.7°C under average-flow conditions and approximately 1.8°C under low-flow conditions at the national border.

The assessment of the potential transboundary impacts of warmed cooling-water discharges from the Paks NPP during the period of the SSLE was based on the analysis and evaluation of archived chemical and biological datasets from 2000-2023, as well as monitoring surveys conducted in 2024 and 2025. Hydrological and heat load models developed for various climate scenarios provided the necessary background information for the ecological interpretation of long-term impacts associated with climate change and different power plant operating conditions, as well as for the delineation of the impact area.

The discharge of warmed cooling water through the warm-water channel into the Danube at river kilometre 1526.2 on the right bank, together with treated non-radioactive technological and municipal wastewater, has been shown to cause hydromorphological alterations, elevated water temperatures, and additional local water quality changes in the River Danube.

Ecological assessments performed at both water-body scale and finer spatial resolution demonstrated that the temperature increase associated with cooling-water discharge and the resulting hydromorphological changes have measurable effects on community structure. However, the minor changes detected in individual chemical parameters do not produce measurable effects on the ecological structure of aquatic communities. Accordingly, both under current conditions and during the period of the SSLE, the actual environmental impact factors are the hydromorphological impacts of water abstraction, the heat load associated with the discharge of warmed cooling water, and the hydromorphological impacts of warmed cooling-water discharge. Among these, thermal loading represents the most significant impact factor. Ecological investigations also confirmed that the actual receptors of these impacts are benthic diatoms (phytobenthos), aquatic macroinvertebrates (macrozoobenthos), and fish communities. In contrast, no measurable changes were detected in the ecological structure of planktonic

organisms (phytoplankton and zooplankton), and therefore these groups cannot be considered impact receptors. The ecological assessment based on the available input data concluded that the strongest impacts and the largest impact area during the period of the SSLE are expected during the simultaneous operation of the Paks NPP and the Paks II NPP.

The results of the high-resolution ecological analyses indicated that, as an immediate short-term impacts, water temperatures of $t_{max} \geq 36°C$ downstream of the discharge cause fish to avoid the affected area. Based on hydrological modelling for the year 2060 under low-flow conditions (790 m^3/s), the extent of this area does not exceed approximately 200 m downstream along the right-bank section of the Danube affected by the thermal plume.

At the same time, it was established that the modification of the structure of receptor communities is primarily caused by the continuous long-term exposure to thermal loading, representing the most extensive impact in terms of spatial extent. The analyses demonstrated that, up to a temperature increase of $\Delta t = +1\text{-}2°C$, community structure remains similar to the upstream reference condition and no direct effects on receptor groups can be detected. This finding is consistent with practical observations, as temperature differences of this magnitude may naturally occur within the Danube ecosystem. Detectable changes in community structure begin to occur at sustained temperature increases of approximately +2-3°C. The ecological threshold identified for the receptor organisms was determined to be $\Delta t \geq 2.5°C$.

Based on the hydrological models, it was determined that, during the simultaneous operation of the Paks and the Paks II NPP, the maximum impact area calculated for the projected low-flow conditions of 2060 extends no more than approximately 18 km downstream from the discharge point. Consequently, it can be clearly concluded that the Danube discharges from the Paks NPP do not result in transboundary impacts for any biological quality element.

8.4. Expected radiological impacts during the period of the SSLE

8.4.1. Assessment methodology and input data

In the assessment of radiological impacts, direct and indirect radiological impacts can be distinguished. Direct radiological impacts are those that affect members of the public directly as external radiation exposure resulting from the operation of the NPP, such as the transport of fresh and spent nuclear fuel, radioactive waste shipments, or the movement of equipment and radiation sources containing radionuclides on their surfaces within the plant site. Indirect radiological effects arise from the gaseous and liquid radioactive discharges of the NPP.

The direct radiological impact associated with the operation of the Paks NPP (i.e., direct exposure from scattered radiation) is already extremely low in the vicinity of the plant, and no impacts can be detected beyond national borders. Consequently, the assessment of potentially transboundary radiological impacts focuses on indirect effects, including the determination of environmental radiation conditions and public radiation doses resulting from radioactive discharges.

The assessment of transboundary radiological impacts was carried out both through a review of previous analyses and through new calculations using the most recent available data. The evaluation also examined how potential changes during the SSLE period, such as changes in meteorological and hydrological conditions or in the lifestyle and consumption habits of local populations, could affect transboundary radiological impacts. The assessment of radiological impacts potentially extending beyond national borders during the continued operation of the NPP was based on the normal operational gaseous and liquid discharges, design basis accidents, and potential gaseous releases associated with severe accidents.

The input data used in the models for determining environmental radiation conditions and public doses included the source term of the release, meteorological and hydrological conditions, and lifestyle and consumption habits of the exposed population. For each operating condition, the applicable assessment tools, source terms, release characteristics, meteorological and hydrological input data, as well as population lifestyle and consumption parameters, were defined. Relevant exposure pathways, receptor locations, and dose quantities to be determined were also identified.

Direct liquid discharges into the Danube may occur only during normal operation. Design basis accidents include leakage or malfunction of the liquid radioactive waste management system and hypothetical releases from liquid storage tanks. However, in such cases the leakage would occur within a plant building, from which radioactive material could only reach the environment through evaporation and release via ventilation systems. The associated activity would be several orders of magnitude lower than that considered for the atmospheric release scenarios assessed. Therefore, no liquid radioactive discharge into the Danube is expected under these accident conditions.

For design basis accidents and severe accidents, the assessment of transboundary impacts associated with aquatic transport was performed assuming that approximately 20% of the total activity released to the atmosphere during gaseous release events is washed out into the Danube by precipitation processes (excluding noble gases).

The difference between the design basis accident analyses and the severe accident analyses lies only in the source terms and release characteristics used. Severe accident analyses were performed for two scenarios involving significant environmental releases and considered representative in terms of both occurrence frequency and event progression. In one severe accident scenario, direct environmental release occurs through a damaged reactor building wall, therefore, the analyses were performed assuming an effective release height of 40 m. In the second severe accident scenario, the release occurs through the ventilation stack, accordingly, the analyses were performed assuming an effective release height of 120 m.

For atmospheric dispersion modelling of gaseous releases, receptor points outside Hungary were defined as the nearest settlements to the NPP site located close to the national borders of neighbouring countries, together with Vienna (Austria). Distances from the plant were determined with an accuracy of approximately 1 km based on the nearest point of each settlement relative to the NPP site.

The receptor locations were assigned to one of sixteen directional sectors around the site. The selected receptor settlements and their characteristics are as follows:

- Slovenia: Pince (~179 km, sector 13, W),
- Croatia: Duboševica (~77 km, sector 9, S),
- Serbia: Riđica (~67 km, sector 8, SSE),
- Romania: Beba Veche (~122 km, sector 6, ESE),
- Ukraine: Solomonovo (~327 km, sector 3, NE),
- Slovakia: Obid (~138 km, sector 1, N),
- Austria: Luising (~187 km, sector 14, WNW),
- Austria: Vienna (~267 km, sector 15, NW).

For the assessment of potentially transboundary impacts associated with radioactive discharges to the Danube, the receptor point was selected as the location where the Danube leaves Hungary and reaches the first populated settlement. This location is Batina, Croatia, situated at 1428 rkm, approximately 98 km downstream from the liquid discharge point of the NPP (1526 rkm).

8.4.2. Transboundary radiological impacts of the independent operation of the Paks NPP

8.4.2.1. Normal operating conditions

For normal operating conditions, annual doses presented in *Table 8.4.2.1-1.* were calculated using the actual gaseous discharge data from 2022, representing the most conservative year for assessment purposes. The results were determined for representative adult individuals and one-year-old children at the selected receptor points outside Hungary. The highest dose was calculated for Duboševica, Croatia, located approximately 77 km south of the NPP. The annual committed effective dose for the representative adult individual was 0.042 nSv, while the corresponding value for a one-year-old child was 0.022 nSv.

The reported values represent the sum of doses arising from all exposure pathways considered in the assessment. As an example, the contribution of individual exposure pathways for Dubošević is presented in *Table 8.4.2.1-2.*

Among the various exposure pathways, the food-chain pathway contributes the largest share of the total committed effective dose for adults, accounting for approximately 52% of the total dose. For adults, approximately 35% of the dose originates from external exposure to radionuclides deposited on the ground surface. The inhalation pathway contributes approximately 12% of the adult dose. For one-year-old children, the largest contribution originates from ground deposition exposure, accounting for approximately 50% of the total dose. Inhalation and food-chain pathways contribute approximately 27% and 22%, respectively, to the total dose received by one-year-old children. Cloud-shine exposure contributes less than 1% of the total dose for both age groups.

Table 8.4.2.1-1. Committed effective doses determined from actual gaseous releases in 2022 under normal operating conditions for representative adult Individuals and one-year-old children

Receptor point	Distance and direction from release point	Committed effective dose [nSv]	
		Adult	One-year-old child
Pince, Slovenia	179 km, W	$9.97 \cdot 10^{-3}$	$5.14 \cdot 10^{-3}$
Dubošević, Croatia	77 km, S	$4.20 \cdot 10^{-2}$	$2.20 \cdot 10^{-2}$
Riđica, Serbia	67 km, S, SE	$3.57 \cdot 10^{-2}$	$1.86 \cdot 10^{-2}$
Beba Veche, Romania	122 km, E, SE	$1.54 \cdot 10^{-2}$	$7.98 \cdot 10^{-3}$
Solomonovo, Ukraine	327 km, NE	$7.89 \cdot 10^{-3}$	$3.97 \cdot 10^{-3}$
Obid, Slovakia	138 km, N	$3.61 \cdot 10^{-2}$	$1.87 \cdot 10^{-2}$
Luising, Austria	187 km, W, NW	$1.21 \cdot 10^{-2}$	$6.21 \cdot 10^{-3}$
Vienna, Austria	267 km, NW	$1.04 \cdot 10^{-2}$	$5.38 \cdot 10^{-3}$

Table 8.4.2.1-2. Committed effective doses determined from actual gaseous releases in 2022 under normal operating conditions for representative adult Individuals and one-year-old children in Dubošević (Croatia), by exposure pathway

Exposure pathway	Committed effective dose [nSv]	
	Adult	One-year-old child
Total	$4.20 \cdot 10^{-2}$	$2.20 \cdot 10^{-2}$
Cloudshine dose	$1.48 \cdot 10^{-4}$	$1.20 \cdot 10^{-4}$
Groundshine dose	$1.48 \cdot 10^{-2}$	$1.10 \cdot 10^{-2}$
Inhalation dose	$5.09 \cdot 10^{-3}$	$5.99 \cdot 10^{-3}$
Food-chain dose	$2.20 \cdot 10^{-2}$	$4.94 \cdot 10^{-3}$

For the assessment of normal operational liquid discharges, calculations were performed using the actual liquid discharge data from 2021, considered the most conservative year for assessment purposes. The discharge was assumed to be continuous and represented as a point source located near the riverbank. *Table 8.4.2.1-3.* presents the calculated committed effective doses for representative adult individuals and one-year-old children at Batina, Croatia, located approximately 98 km downstream of the NPP. The dose resulting from the actual liquid discharges of the NPP in 2021 was dominated by the contribution of ^{14}C, accounting for more than 90% of the total dose for both representative adults and one-year-old children. The total dose was dominated by internal exposure resulting from fish consumption. Due to differences in consumption rates, the internal and total doses calculated for adults were slightly higher than those calculated for one-year-old children.

Table 8.4.2.1-3. Committed effective doses determined from actual liquid releases in 2021 under normal operating conditions for representative adult Individuals and one-year-old children in Batina (Croatia), by exposure pathway

Exposure pathway	Committed effective dose [nSv]	
	Adult	One-year-old child
Total	$1.13 \cdot 10^{1}$	$1.01 \cdot 10^{1}$
Swimming – external skin dose from beta radiation	$1.79 \cdot 10^{-5}$	
Swimming – external dose from gamma radiation	$1.54 \cdot 10^{-5}$	
Water-related activities – external dose from gamma radiation	$3.16 \cdot 10^{-2}$	
Fish consumption – internal dose	$1.12 \cdot 10^{1}$	$1.01 \cdot 10^{1}$

Based on the results, the radiological impacts beyond the national border arising from normal operational gaseous and liquid discharges can be classified as neutral impacts, remaining substantially below both the dose constraint of 90 μSv/year and the upper threshold established for neutral radiological impacts.

8.4.2.2. Design basis accidents

For design basis accidents, the scenarios considered were identical to those used in *Chapter 5.3.* for the assessment of public radiation exposure. The highest doses resulting from atmospheric releases were obtained for release scenario No. 3 (break of the DN 90 mm pressurizer injection pipe at 1485 MW thermal power under the assumption of total loss of off-site and on-site power supply).

The doses calculated for this design basis accident scenario are summarized in *Table 8.4.2.2-1.* for representative adults and one-year-old children at the investigated receptor locations. The highest values were obtained for Riđica, Serbia, located approximately 67 km south-southeast of the NPP, and Duboševica, Croatia, located approximately 77 km south of the plant. The calculated committed effective dose for the representative adult individual was 7.57 nSv, while the corresponding value for a one-year-old child was 5.88 nSv.

Table 8.4.2.2-1. Committed effective doses determined for release scenario No. 3 of the design-basis accident, for representative adult Individuals and one-year-old children

Receptor point	Distance and direction from release point	Committed effective dose [nSv]	
		Adult	One-year-old child
Pince, Slovenia	179 km, W	2.93	2.25
Duboševica, Croatia	77 km, S	7.56	5.88
Riđica, Serbia	67 km, S, SE	7.57	5.87
Beba Veche, Romania	122 km, E, SE	4.94	3.79
Solomonovo, Ukraine	327 km, NE	1.81	1.38
Obid, Slovakia	138 km, N	4.70	3.61
Luising, Austria	187 km, W, NW	2.35	1.82
Vienna, Austria	267 km, NW	1.57	1.22

The analyses demonstrate that even the committed effective dose associated with the design basis accident scenarios resulting in the highest public exposure does not exceed 90 μSv. Consequently, transboundary impacts associated with design basis accidents remain more than one order of magnitude below the upper limit established for neutral impacts.

No direct liquid radioactive discharge to the Danube occurs during design basis accidents. Therefore, the assessment of transboundary impacts associated with aquatic transport was based on the assumption that approximately 20% of the total activity released to the atmosphere

during design basis accident scenarios is washed out into the Danube through atmospheric deposition processes (excluding noble gases). The washout fraction was determined based on the proportion of the released contamination deposited onto a hypothetical area of 700×700 m during the time required for the radioactive plume to pass over the area at the relevant wind speed. The deposited fraction of the atmospheric source term was then used as the source term for the aquatic transport calculations. For aquatic exposure pathways, the highest doses were again obtained for scenario No. 3 (break of the DN 90 mm pressurizer injection pipe at 1485 MW thermal power under total station blackout conditions).

Table 8.4.2.2-2. presents the calculated committed effective doses for representative adults and one-year-old children at Batina, Croatia, located 98 km downstream of the NPP, for the design basis accident scenario considered. Exposure duration was determined based on the time required for the radioactive contamination to pass through the river section, weighted according to the annual occupancy factor. During this period, the higher of the two external aquatic exposure pathways – swimming (immersion in water) and water-related activities (such as staying on the riverbank, boating, or fishing) – was considered. In this case, the dominant pathway was water-related activities. Among the radionuclides released to the atmosphere and subsequently washed into the river, cesium and iodine isotopes provided the largest contribution to the dose, accounting for approximately 70-80% of the total dose for both adults and one-year-old children. The dose conversion factors used for calculating internal exposure from fish consumption are higher for one-year-old children than for adults for these radionuclides, resulting in correspondingly higher internal doses for the younger age group.

Table 8.4.2.2-2. Committed effective doses determined for representative adult individuals and one-year-old children in Batina (Croatia), resulting from washout of atmospheric releases to the Danube in design basis accident scenario No. 3, by exposure pathway

Release scenario	**Design-basis accident scenario No. 3**	
Exposure pathway	**Committed effective dose [μSv]**	
	Adult	**One-year-old child**
Total	14.2	14.4
Water-related activities – external gamma dose	13.1	
Fish consumption – internal dose	1.06	1.26

The doses calculated for aquatic exposure pathways were higher than those calculated for atmospheric exposure pathways for the same accident scenario. The primary reason is that atmospheric dispersion occurs within a much larger volume, allowing the radioactive plume to spread and dilute significantly before reaching distant receptor locations. In contrast, aquatic transport is confined within the river channel, where dilution occurs within a substantially smaller volume of water.

The calculations demonstrate that, even under the highly conservative assumptions applied in the assessment scenario, the doses determined for design basis accidents remain well below the upper threshold of 90 μSv established for neutral impacts.

The calculation results obtained for aquatic exposure pathways resulting from the washout of atmospheric releases into the Danube cannot be directly added to the doses calculated for atmospheric exposure pathways based on the same gaseous release, as the simultaneous occurrence of the two scenarios is not physically possible. If radioactive material is washed out from the atmospheric plume into the Danube to such a significant extent, less activity remains in the atmosphere, resulting in lower doses associated with atmospheric dispersion pathways.

8.4.2.3. Impact of potential changes during SSLE

The assessment also included an evaluation of how potential changes in factors influencing public radiation exposure during the SSLE period could affect potential transboundary environmental impacts and public radiation doses.

For the dose consequences of gaseous releases, sensitivity analyses were performed regarding changes in meteorological parameters affecting atmospheric dispersion calculations; population lifestyle characteristics affecting dose assessments; and consumption rates of locally produced foodstuffs. For liquid releases and their consequences via aquatic transport pathways, the assessment examined how changes in hydrological parameters, particularly variations in Danube discharge and river gradient, as well as changes in the duration of water-related activities and consumption rates of potentially contaminated fish caught in the Danube, could affect the calculated doses.

The sensitivity analyses of meteorological parameters demonstrated that, at transboundary distances, extreme deviations from the most common meteorological conditions, such as increased precipitation intensity, increased wind speed, or shifts toward more unstable atmospheric stability classes, result in reduced doses. For example, under a representative meteorological scenario, increasing precipitation intensity from an average value of 0.06 mm/h to 2.2 mm/h reduced the 50-year committed effective dose at the nearest receptor locations beyond the national border by approximately 35-55% for both design basis accidents and severe accidents. This occurs because more intense precipitation enhances washout of radioactive material from the plume near the release point, thereby reducing the amount of activity remaining airborne and available for transport to more distant locations. Changes in population lifestyle and consumption habits may lead to increases in doses resulting from gaseous releases. However, even the plausible future magnitude of such changes would not result in particularly significant increases (i.e. exceeding approximately 40%). Therefore, it is not expected that future changes in lifestyle and consumption habits would materially alter the conclusions of the assessment or the significance of the identified impacts.

The washout of airborne contamination into the Danube is already treated in a highly conservative manner within the analyses. The sensitivity studies demonstrated that further variations in washout rates arising from changes in meteorological conditions would not result in changes exceeding 13% in the committed effective doses calculated for aquatic exposure pathways. Consequently, no significant increase in potentially transboundary radiological impacts is expected as a result of changes in washout processes.

The aquatic transport analyses demonstrated that a substantial decrease in river discharge (from average-flow to low-flow conditions) could increase the committed effective dose resulting from normal operational liquid releases by less than a factor of three. However, even under such conditions, the resulting radiation exposure remains well below both the dose constraint of 90 μSv/year and the upper threshold for neutral radiological impacts. For normal operational liquid releases, almost the entire dose (approximately 99%) originates from internal exposure due to fish consumption. Consequently, among the relevant lifestyle parameters, only changes in fish consumption rates can significantly affect the total committed effective dose. Changes in other aquatic exposure pathways have negligible influence; for example, even doubling the annual duration of water-related activities would increase the total dose by less than 1%.

8.4.2.4. Severe accidents

The assessment of severe accidents was performed for the following two representative scenarios involving significant environmental releases, selected as characteristic cases for evaluating severe accident consequences:

- Case 1: Station blackout with the reactor and containment remaining intact, at nominal power.
- Case 2: A 233 mm large-break loss-of-coolant accident combined with failure of the sump isolation valves and unsuccessful containment isolation.

The release source term was defined by concentrating the significant environmental release into the first 48 hours following the accident. Accordingly, atmospheric dispersion modelling was performed for a time-dependent release lasting 48 hours. Of the two scenarios, severe accident scenario No. 2 resulted in the higher doses, therefore, the results presented below correspond to this case.

Table 8.4.2.4-1. summarizes the doses calculated for representative adults and one-year-old children at the investigated receptor locations. Among the exposure pathways the external exposure from the radioactive cloud, the external exposure from deposited activity on the ground, the internal exposure due to inhalation, and the internal exposure via the food chain were determined. For cloud immersion and inhalation pathways, the exposure duration corresponds to the passage time of the radioactive plume. For ground deposition and food-chain pathways, the assessment considers lifetime exposure periods (50 years for adults and 70 years for one-year-old children). The highest value was calculated for Dubоševica, Croatia, located approximately 77 km south of the NPP. The calculated committed effective dose for the representative adult individual was 5.4 mSv, while the corresponding value for a one-year-old child was 2.0 mSv.

Table 8.4.2.4-1. Committed effective doses determined for severe accident release scenario No. 2 for representative adult Individuals and one-year-old children

Receptor point	Distance and direction from release point	Committed effective dose [nSv]	
		Adult	One-year-old child
Pince, Slovenia	179 km, W	$1.23 \cdot 10^3$	$4.34 \cdot 10^2$
Dubоševica, Croatia	77 km, S	$5.35 \cdot 10^3$	$2.00 \cdot 10^3$
Riđica, Serbia	67 km, S, SE	$4.94 \cdot 10^3$	$1.82 \cdot 10^3$
Beba Veche, Romania	122 km, E, SE	$2.04 \cdot 10^3$	$7.04 \cdot 10^2$
Solomonovo, Ukraine	327 km, NE	$7.23 \cdot 10^2$	$2.36 \cdot 10^2$
Obid, Slovakia	138 km, N	$3.21 \cdot 10^3$	$1.14 \cdot 10^3$
Luising, Austria	187 km, W, NW	$1.02 \cdot 10^3$	$3.62 \cdot 10^2$
Vienna, Austria	267 km, NW	$9.10 \cdot 10^2$	$3.25 \cdot 10^2$

In the event of a severe accident, it can reasonably be assumed that emergency protective actions (primarily sheltering or food consumption restrictions) would be implemented in those areas where the Hungarian National Nuclear Emergency Response Plan (OBEIT) requires such measures based on the projected doses calculated without the application of protective actions. It can further be assumed that the emergency response plans of Hungary's neighbouring countries contain similar procedures, as they are also developed in accordance with the requirements of the IAEA's General Safety Requirements Part 7 (Preparedness and Response for a Nuclear or Radiological Emergency, IAEA, Vienna, 2015), and that the competent authorities of those countries would cooperate with the Hungarian emergency response organizations during an accident. If food consumption restrictions are successfully implemented, i.e., assuming that consumption of contaminated food is reduced to zero, and only external exposure and inhalation pathways are considered, the resulting doses are typically reduced to approximately one-third of their original values at all receptor locations.

For sheltering, the dose calculations assumed that residents remain indoors throughout the passage of the radioactive plume and engage only in low-activity indoor behaviour. Under these assumptions, sheltering reduces cloudshine and groundshine doses by approximately 20-30%, while inhalation doses are reduced by nearly 70% for adults. Nevertheless, because the dominant contribution to the total dose arises from food-chain exposure, the total dose is reduced by only approximately 10% compared with the case without sheltering.

The severe accident doses expected when both food consumption restrictions and sheltering are implemented are presented in *Table 8.4.2.4-2.* It can be seen that the introduction of these protective actions reduces the total committed effective dose by approximately 50-80% (for example, at Dubоševica, the maximum dose is reduced by 48% for one-year-old children and by 83% for adults).

Table 8.4.2.4-2. Committed effective doses determined for severe accident release scenario No. 2 for representative adult individuals and one-year-old children assuming food consumption restrictions and sheltering

Receptor point	Distance and direction from release point	Committed effective dose [μSv]	
		Adult	One-year-old child
Pince, Slovenia	179 km, W	$1.03 \cdot 10^2$	$1.55 \cdot 10^2$
Dubošević, Croatia	77 km, S	$4.93 \cdot 10^2$	$7.65 \cdot 10^2$
Riđica, Serbia	67 km, S, SE	$4.49 \cdot 10^2$	$6.86 \cdot 10^2$
Beba Veche, Romania	122 km, E, SE	$1.68 \cdot 10^2$	$2.45 \cdot 10^2$
Solomonovo, Ukraine	327 km, NW	$5.73 \cdot 10^1$	$7.79 \cdot 10^1$
Obid, Slovakia	138 km, N	$2.73 \cdot 10^2$	$4.12 \cdot 10^2$
Luising, Austria	187 km, W, NW	$8.55 \cdot 10^1$	$1.30 \cdot 10^2$
Vienna, Austria	267 km, NW	$7.61 \cdot 10^1$	$1.16 \cdot 10^2$

The assessment of potentially transboundary radiological impacts associated with aquatic transport of radioactive contaminants was performed by considering the washout of airborne releases from severe accidents into the Danube. The washout fraction was assumed to be 20%, consistent with the methodology applied for design basis accidents. Accordingly, the deposited fraction of the atmospheric source term was used as the source term for the aquatic transport modelling.

The doses for aquatic exposure pathways are presented for severe accident scenario No. 2, which resulted in the higher calculated doses. *Table 8.4.2.4-3.* presents the calculated committed effective doses for representative adults and one-year-old children at Batina, Croatia, located approximately 98 km downstream of the NPP. Among the aquatic exposure pathways, only the pathway resulting in the higher dose was considered. Of the radionuclides released into the atmosphere and subsequently washed into the river, isotopes of cesium (^{134}Cs, ^{136}Cs, ^{137}Cs) and iodine (^{131}I, ^{133}I, ^{135}I) were the dominant contributors, accounting for approximately 70% of the external gamma dose. The calculation of internal exposure from fish consumption was based on the conservative assumption that residents consume their entire annual quantity of fish containing radioactive contamination immediately after the release event.

Table 8.4.2.4-3. Committed effective doses determined for representative adult Individuals and one-year-old children at Batina (Croatia), assuming washout of atmospheric releases into the Danube for severe accident scenario No. 2, by exposure pathway

Release scenario	Severe accident scenario No. 2	
Exposure pathway	Committed effective dose [μSv]	
	Adult	One-year-old child
Total	$5.34 \cdot 10^3$	$5.02 \cdot 10^3$
Water-related activities – external gamma dose	$4.06 \cdot 10^3$	
Fish consumption – internal dose	$1.28 \cdot 10^3$	$9.64 \cdot 10^2$

Under these highly conservative assumptions, the committed effective dose calculated for Batina in severe accident scenario No. 2 amounts to 5.3 mSv for adults and 5.0 mSv for one-year-old children, assuming one year of fish consumption exposure and exposure to water-related activities for the duration of the passage of the contamination plume. For comparison, the worldwide average annual natural background radiation dose is approximately 2.4 mSv[15]. The contribution of the external gamma dose from water-related activities to the total dose is approximately 76% for adults and 81% for one-year-old children, while fish consumption

[15] United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionizing radiation. UNSCEAR 2008 Report, Volume I: SOURCES, Report to the General Assembly Scientific Annexes A and B, ISBN 978-92-1-142274-0.

contributes approximately 24% and 19%, respectively. For aquatic exposure pathways, emergency protective actions may also be implemented, including restrictions on water-related activities and fish consumption. The implementation of such measures can substantially reduce the committed effective dose, effectively to near-zero levels.

The dose values calculated for aquatic exposure pathways resulting from washout of atmospheric releases cannot be added to the dose values determined for atmospheric exposure pathways arising from the same airborne release, since the simultaneous occurrence of these two scenarios is not physically possible.

8.4.3. Transboundary radiological impacts of the combined operation of the Paks NPP and the Paks II NPP

The cumulative public dose, resulting from the normal operation of the Paks NPP, the Paks II NPP, and the SFISF remains significantly below the dose constraint of 90 μSv/year established separately for the Paks NPP and the Paks II NPP, even within a 30 km radius of the site. Accordingly, it can be concluded that no potential transboundary radiological impacts are expected from the combined normal operation of these three facilities (the Paks NPP, the Paks II NPP, and the SFISF). Provided that the applicable dose constraints are complied with, the impacts at receptor locations beyond Hungary's borders remain within the neutral impact category.

In the event of an accident, or severe accident postulated separately for any of the currently operating, or future nuclear facilities at the site, the impacts originating from the other two facilities – assumed to remain in normal operation during the event – would not materially influence the results of the analyses, either in terms of environmental releases or resulting public radiation exposure. The analyses do not require the assumption that accidents, or severe accidents occur simultaneously at multiple nuclear facilities currently operating or planned at the site. This is because, accident consequences associated with the SFISF, or the Paks II NPP would be significantly lower than those calculated for a comparably severe accident at the Paks NPP. Furthermore, even in the unlikely event of simultaneous incidents, no interactions between the facilities are expected that would result in increased radiation doses. Moreover, although the probability of simultaneous accidents is extremely low, even in such a theoretically conceivable case the temporal progression of the individual events would not be identical, and therefore the timing of radioactive releases would differ. As a consequence, the resulting radioactive plumes would most likely be dispersed under different meteorological conditions and would propagate in different directions. While this could potentially increase the overall geographical area affected, the maximum doses calculated separately for each accident scenario could not simply be added together. Similarly, the assessment did not consider scenarios involving simultaneous accidents occurring in multiple reactor units of the Paks NPP. The analyses were performed using conservative and best-estimate approaches, focusing on safety-relevant scenarios above a defined probability threshold. Therefore, they do not include theoretically possible, but extremely low-probability events, such as simultaneous accidents affecting multiple nuclear facilities or multiple reactor units.

9. Measures to reduce and monitor the expected environmental impact during the extended operating lifetime

During the period of the SSLE of the Paks NPP, environmental compliance can be achieved primarily by ensuring the safety of the NPP. The MVM Paksi 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 the environmental impacts caused by the NPP in operation for several decades, the conclusions of this EIA, and the regulations already applied at the NPP – no further measures have been formulated in order to protect the environment and human health, or to avoid, prevent or reduce possible strain, disturbance or pollution.

Abbreviations

ABOS	Safety classification of nuclear power plant components
ALARA	As Low As Reasonably Achievable
ÁNTSZ OTH	Office of the Chief Medical Officer in the State Public Health and Medical Officer Service
ÁOKU	State-Oriented Management Instructions
ASNR	L'Autorité de sûreté nucléaire et de radioprotection – French Authority for Nuclear Safety and Radiation Protection
ATEX	Atmospheres Explosible – includes two EU directives in the field of explosion protection: the 1999/92/EC Directive on health and safety at work and the 2014/34/EU Directive on product standards for potentially explosive atmospheres
ATWS	Anticipated Transient Without Scram
ÁVIT	Emergency Management and Response Plan
Á-NÉR	General National Habitat Classification System
BCGO	Baranya County Government Office
BEPU	Best Estimate Plus Uncertainty
BME	Budapest University of Technology and Economics
BOD	Biochemical Oxygen Demand
BTEX	Benzene, toluene, ethylbenzene and xylene are a group of volatile aromatic hydrocarbons
BWR	Boiling-Water Reactor
CCA	Canonical Correspondence Analysis
CEC	Cavity Enclosure Container
CfD	Contract-for-Difference
CLC	Corine Land Cover, the European Environment Agency's land cover database
CLMS	Copernicus Land Monitoring Service, a European system for monitoring the Earth's surface
COD	Chemical oxygen demand
CORINE	Corine Land Cover, the European Environment Agency's land cover database
DBA	Design Basis Accidents (state included in the design basis)
DBC	Design Basis Conditions
DBC1	Normal operation (Design basis condition 1)
DBC2	Anticipated operational occurrences (Design basis condition 2)
DEC	Design Extension Conditions
DEC1	Complex Sequences (Design extension conditions 1)
DEC2	Severe accident (Design extension conditions 2)
DN	Nominal diameter
ECCS	Emergency Core Cooling System
EEA	European Environment Agency
EEE	Earthquake Environmental Effect
EFG	Electric fishing gear – direct current / direct pulse current electric fishing machine (electric sampling device)
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMC	Electromagnetic compatibility
EOV	Unified National Projection System
EPR	European Pressurised Reactor
EQR	Environmental Quality Ratio

ERPCS	Environmental Radiation Protection Control System
ERPG	Emergency Response Planning Guidelines
ERPG-2	Maximum concentration that does not cause irreversible health damage after one hour of exposure
ETG	Electric trawling gear (electric bottom net), sampling device for the investigation of benthic fish in watercourses
EU	European Union
FAVÖKO	Groundwater-Dependent Terrestrial Ecosystems
FHF	Liquid wastewater treatment technology
FSAR	Final Safety Analysis Report
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GWP	Global Warming Potential
HAEA (OAH)	Hungarian Atomic Energy Authority
HAZOP	Hazards and Operability Analysis
HCSO	Hungarian Central Statistical Office
HIPA	Local business tax
HÉSZ	Local building regulation
HI-STORM UMAX	Holtec International STORage Module Underground MAXimum Capacity – Holtec International's underground spent fuel storage system
HPGe	High Purity Germanium
HUN-REN EK-CER	HUN-REN Centre for Energy Research
HWL	Highest Water Level
IAEA	International Atomic Energy Agency
ICP	Inductively coupled plasma
ICRP	International Commission on Radiological Protection
IGALL	International Generic Aging Lessons Learned (a program initiated by the International Atomic Energy Agency)
IPCC	Intergovernmental Panel on Climate Change
IPS	Index of Pollution Sensitivity – diatom index used in ecological status assessment
ITS	Integrated Settlement Development Strategy
KEKKH	Central Office for Public Administration and Electronic Public Services
KiESZ	Emission Control Regulation
KKSER	Emission and environmental radiation monitoring system
KöESZ	Environmental Monitoring Regulation
LCM	Land Change Modeller
LQ	Low-water discharge
LWL	Lowest Water Level
LWPT	Liquid Wastewater Processing Technology
mBSl	Meters above Baltic Sea level
MEKH	Energy and Public Utility Regulatory Authority
MLP	Multilayer perceptron – artificial neural network
MNDS	Non-metric Multidimensional Scaling
MPC	Multi-Purpose Canister
MQ	Mean water discharge
MVDS	Modular Vault Dry Storage – modular dry storage (for nuclear power plant spent fuel assemblies)

MZB	Macrozoobenthos
NAGiS	National Adaptation Geo-information System
NECP	National Energy and Climate Plan
NÉBIH	National Food Chain Safety Office
NÖSZTÉP	National Ecosystem Base Map
NRC (US NRC)	United States Nuclear Regulatory Commission
OBEIT	National Nuclear Emergency Response Plan
OLM	National Air Pollution Monitoring Network
OTrT	National Spatial Plan
NPP	Nuclear Power Plant
NRC (U.S. NRC)	United States Nuclear Regulatory Commission
NRWR	National Radioactive Waste Repository
NSC	Nuclear Safety Code (Annexes 1-10 of the OAH Decree 1/2022. (IV. 29.) on the nuclear safety requirements of nuclear facilities and on related regulatory activities
Paks NPP	Paks Nuclear Power Plant
Paks II NPP	Paks II Nuclear Power Plant
PAH	Polycyclic Aromatic Hydrocarbons
PB	Phytobenthos
PCB	PolyChlorinated Biphenyls
PCD	Preliminary Consultation Document
PFDHA	Probabilistic Fault Displacement Hazard Analysis
PIT	Personal Income Tax
PP	Phytoplankton
PRISE	Primary-to-Secondary leaking
PSA	Probabilistic safety assessment
PSAR	Preliminary Safety Analysis Report
PSHA	Probabilistic Seismic Hazard Assessment
PTS	Pressurized Thermal Shock
PURAM	Public Limited Company for Radioactive Waste Management
PWR	Pressurized Water Reactor
RBMP	River Basin Management Plan
RCP	Representative Concentration Pathways
SAC	Special Areas of Conservation
SALTO	Safety Aspects of Long-Term Operation (International Atomic Energy Agency review activity)
SBKU	Severe Accident Management Guide
SFISF	Spent Fuel Interim Storage Facility
SLR	Subsequent License Renewal – further extension of the operating life of nuclear power plants, i.e. multiple renewals of the validity of the original license
SSLE	Subsequent Service Life Extension
SZBV	Control and safety system
TeIR	National Spatial Development and Spatial Planning Information System
TFP	Total Factor Productivity
TIR	Nature Conservation Information System
TL	Thermoluminescence (dosimetry)
TLAA	Time-Limited Aging Analysis
TPH	Total Petroleum Hydrocarbons
TPH-GC	Total Petroleum Hydrocarbons analysis by Gas Chromatography

TSPM	Total Suspended Particulate Matter
UHRS	Uniform Hazard Response Spectra
ÜKSER	Operational Environmental Radiation Monitoring System
VCT	Vertical Cask Transporter
VVER	Water-moderated, water-cooled power reactor
VVM	Vertical Ventilated Module
WENRA	Western European Nuclear Regulators' Association
WFD	Water Framework Directive

Annexes